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SPECIAL REPORT
SPACE

DARK ENERGY DILEMMA

Why NASA's planet-hunting astrophysics telescope is an easy budget target, and what defeat would mean PAGE 24

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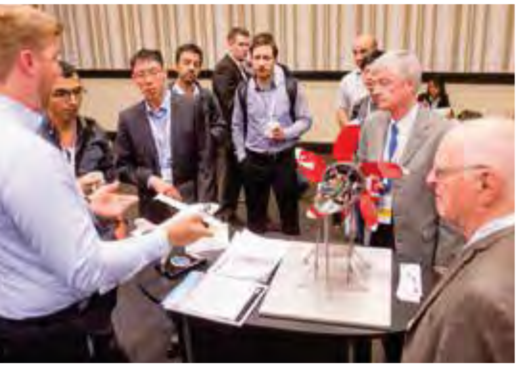

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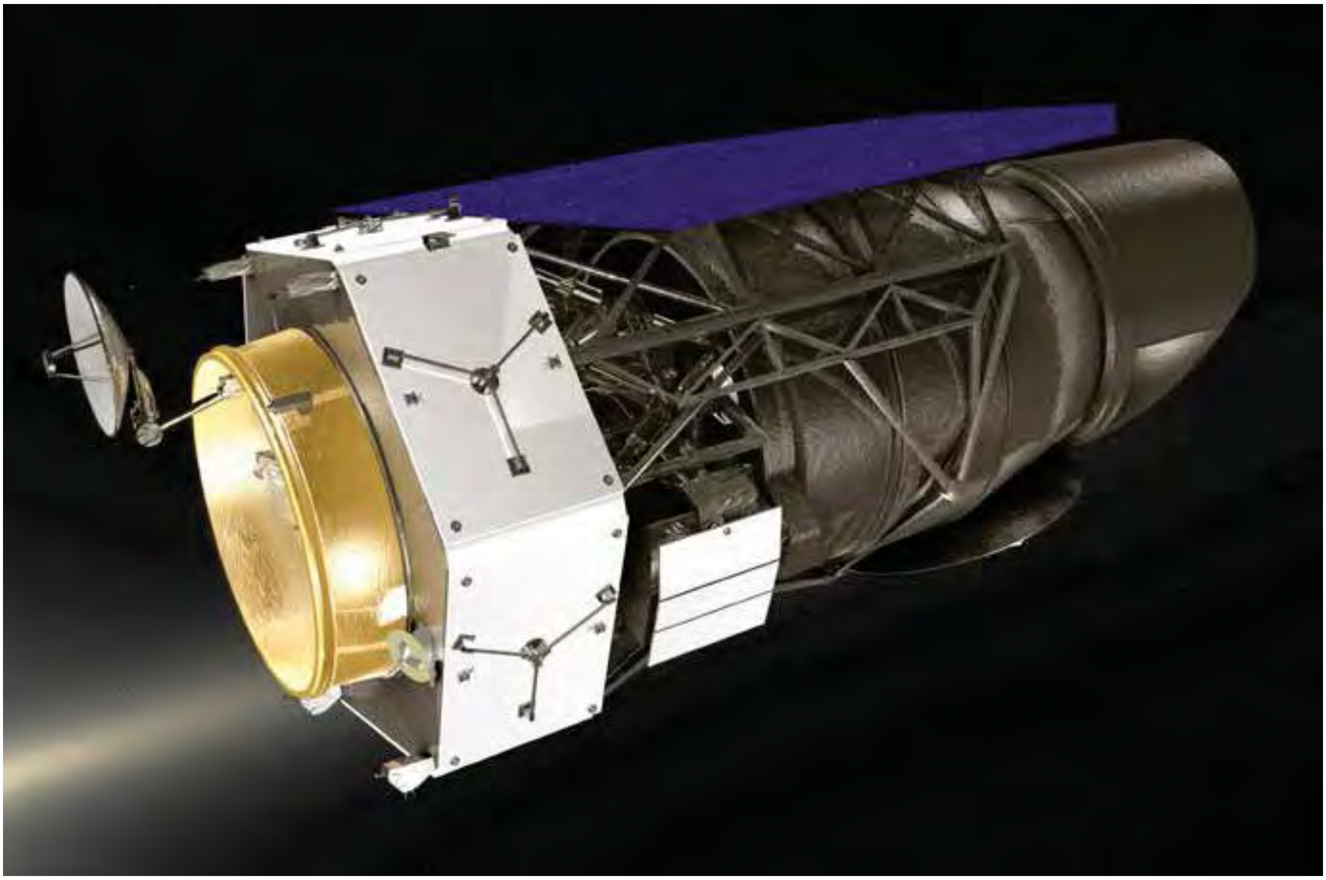

On the cover: A silhouette of NASA's Wide Field Infrared Survey Telescope

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AEROSPACE AMERICA

APRIL 2018, VOL. 56, NO. 4

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Shaping the Future of Aerospace

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Tom Jones

Tom flew on four space shuttle missions. On his last flight, STS-98, he led three spacewalks to install the American Destiny Laboratory on the International Space Station. He has a doctorate in planetary sciences.

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Amanda Miller

Amanda is a freelance reporter and editor based near Denver with 20 years of experience at weekly and daily publications.

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Tom Risen

As our staff reporter, Tom covers breaking news and writes features. He has reported for U.S. News & World Report, Slate and Atlantic Media.

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Debra Werner

A frequent contributor to Aerospace America, Debra is also a West Coast correspondent for Space News.

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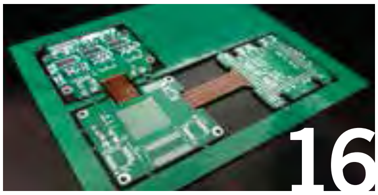
DEPARTMENTS



Beating Silicon Valley at its own game

This month and next, students will head to fields in Wichita, Kansas, and The Plains, Virginia, for two rites of spring that are taking on increased importance given the fierce competition among industries to attract the sharpest and most passionate minds.

I'm talking about AIAA's annual Design Build Fly aircraft competition for undergraduate teams from the U.S. and abroad, and the Team America Rocketry Challenge for U.S. students in grades 7 through 12.

In Design Build Fly, teams design and build remote-controlled aircraft and then gather for a flyoff to see who can best meet a rigorous set of requirements that are different each year. Last year's flyoff drew 73 teams from as far away as Slovenia and India.

In the rocketry challenge, teams of students from around the U.S. must build and fly rockets that can carry a raw egg, sometimes two, to a specified altitude and back within a required time without breakage. The specific rules and parameters are different each year. On average, five thousand students compete locally to be among the 100 teams that gather at The Plains outside Washington, D.C., in May for the finals of this competition put on by the Aerospace Industries Association and the National Association of Rocketry.

So, if you're one of those who worries that the best and brightest STEM minds are being lured to Silicon Valley or Wall Street to write code instead of revolutionizing aircraft or spacecraft, I would suggest that competitions like these are among the best ways to fight back.

Silicon Valley's products are in the hands of children soon after the crib if not while they are still in it. Children on average get their first smartphone by age 10, according to the New York Times, citing 2016 research by the Influence Central marketing firm. That is down from 12 in 2012. And of course kids start playing with mom's or dad's phone much earlier.

Being human, it's only a matter of time before some of these kids start wondering how these games, apps and devices work; how they might make them do even more amazing things. Some of them will one day conceive of the next big step in information devices and concepts.

I would not begrudge any young person for pursuing an education and career that leads to Silicon Valley, to Wall Street or even outside the world of science and technology. The point is to empower kids to find their passions. If a young person never gets the chance for a hands-on encounter with aerospace technology, one that's the equivalent of playing with the code of a computer game, then he or she did not truly make a choice.

That's the timely problem that the surging interest in aircraft and rocket challenges is beginning to solve. ★

▲ John Langford, who will become AIAA president in May, works as the range safety officer at the 2017 Team America Rocketry Challenge national finals.

National Association of Rocketry

Ben Iannotta, editor-in-chief, beni@aiaa.org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It's Been An Honor

It's hard to believe that this is my last column as AIAA president. I am proud of what we have accomplished together and to have led AIAA during a period of positive change and organizational evolution. Although our transition to the new governance structure is ongoing, I believe that we are already much better positioned to be flexible and adapt as necessary to better serve our members and the industry. There are so many people who made possible our successful transition to date, including Sandy Magnus, my predecessors as president, Jim Albaugh and Mike Griffin, and my fellow volunteer leaders and, of course, all of you, the members. We shared the extraordinary vision, dedication, courage to do what was right, rather than what was easy. Because of this hard work, our Institute is now on a path to be strategically focused, relevant, and better positioned to deliver programs and events that will help our members and the global aerospace industry flourish.

The changes put into motion over the past few years are already paying dividends. This January's AIAA SciTech Forum in Kissimmee, FL, had the largest attendance ever—with more than 4,200 professional and student participants from 39 countries and all 50 states. High-level discussions about "flying cars," digital engineering, and autonomous vehicles packed rooms. Attendees dove into the details during technical and Forum 360 sessions covering ground-breaking aerospace technical and scientific research, with the session on "Disrupting Aerospace Business Models" garnering more than 110,000 views on Livestream! Our forum event strategy is working!

As you know, next year is the 50th anniversary of Apollo 11 and the first manned lunar landing. I am excited that the International Astronautical Federation selected AIAA to host the 70th International Astronautical Congress in Washington, DC, in October 2019 during this pivotal time. The event will bring together thousands of decision makers from all sectors of the global space industry, creating opportunities to collaborate with top international innovators and discuss the latest space discoveries and advancements—and what that next giant leap might be.

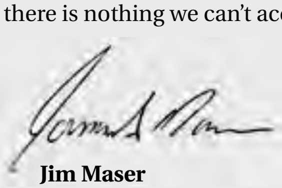
Giving AIAA's members a more influential voice is part of AIAA's mission and a focal point of the new governance structure, which provides you with a greater say in AIAA's future. We also launched a new social platform in January to connect our members to each other and bring the aerospace community together. AIAA Engage **(engage.aiaa.org)** is a place where you can meet fellow aerospace professionals, share your challenges, float new ideas, build your network, and further your career. The platform has resonated with our student members, who are reaching out to AIAA's experienced members for advice. There are already hundreds of active discussions ranging from space systems engineering to technical standards. AIAA Engage soon will be adding section-specific sites so members can discuss local issues.

AIAA is always looking ahead. During my tenure, the Institute formalized its efforts to increase diversity and inclusion as a starting point to a long-term and meaningful commitment. We as an Institute and industry have much work to do in this area but we've gotten the ball rolling and set the tone for the future.

As my term ends, we are also saying goodbye to amazing colleagues and welcoming new ones. While it took scores of people to transform AIAA into a more nimble and essential organization, few had a deeper impact than Sandy Magnus. Sandy's energy, courage, and determination were key to many of the strategic changes and "wins" we had during the past five years. She leaves the Institute both financially stable and well positioned for the future. Her strategic vision and determination led the way. I know I speak for her staff and fellow members when I wish her all the best in her next adventure.

We are excited and fortunate to have Dan Dumbacher take the helm as the Institute's new executive director. He has been an AIAA member for more than 30 years. I certainly can tell you that Dan has taken the role with an amazing amount of enthusiasm and energy, and I am sure that Dan's experience in government, academia, and his work with private industry during 35 years at NASA will help take AIAA to the next level. In May, I will hand off the president's gavel to my successor, John Langford. John, a member for more than 40 years, is CEO and president of Aurora Flight Sciences, now a Boeing Company, and has the forward-thinking entrepreneurial spirit that is sure to help draw a new generation of aerospace professionals to AIAA.

Thank you for the opportunity to be your president. I look forward to working with Dan and John for the rest of my term, and then as chair of the AIAA Foundation. We are all part of a tremendous organization with limitless potential. If we remain future-focused and increase our reach, relevance, and engagement there is nothing we can't accomplish together. ★



Jim Maser
AIAA President

A Grumman F4F-3 Wildcat
Paul G. Allen

A Douglas TBD-1 Devastator torpedo bomber found with the wreckage of the USS Lexington.
Paul G. Allen

Rare World War II planes found

BY TOM RISEN | tomr@aiaa.org

Historians now have color images of rare World War II planes, and families know the final resting place of 216 U.S. sailors and airmen killed during the Battle of the Coral Sea, following the research vessel Petrel's discovery of a wrecked aircraft carrier scuttled in 1942.

The Petrel researchers located the wreckage of the USS Lexington on the floor of the Coral Sea 3,000 meters deep and 800 kilometers off the eastern coast of Australia, according to a March press release from Microsoft co-founder Paul Allen's team. Researchers located the wreck with the sonar and sea floor mapping instruments on a Remus 6000 autonomous underwater vehicle built by Norway-based Kongsberg, which says the vessel can dive to 6,000 meters. A separate remotely operated underwater vehicle with LED lights videotaped the wreckage. The expedition was funded by Allen, who has paid for other attempts to locate the wreckage of World War II ships.

Japanese fighter planes launched from aircraft carriers severely damaged the Lexington, forcing the destroyer USS Phelps to scuttle the vessel on May 8, 1942, after the surviving crew abandoned ship.

The Battle of the Coral Sea was "the first pure aircraft carrier battle," meaning one in which opposing ships attacked each other with aircraft without directly seeing each other, says Laurence Burke, U.S. naval aviation curator at the National Air and Space Museum in Washington, D.C.

The Lexington was also notable as a "very unusual aircraft carrier," since it was converted from a battle cruiser, says retired U.S. Marine Col. Mark Cancian, a military expert at the Center for Strategic and International Studies in Washington, D.C.

The 35 U.S. planes that sank onboard the Lexington included Grumman F4F-3 Wildcat fighter planes and Douglas TBD-1 Devastator torpedo bombers. The painted decals on some of the planes are still intact, similar to some other wrecks at that depth, where there is little oxygen or life to erode the paint, Burke says.

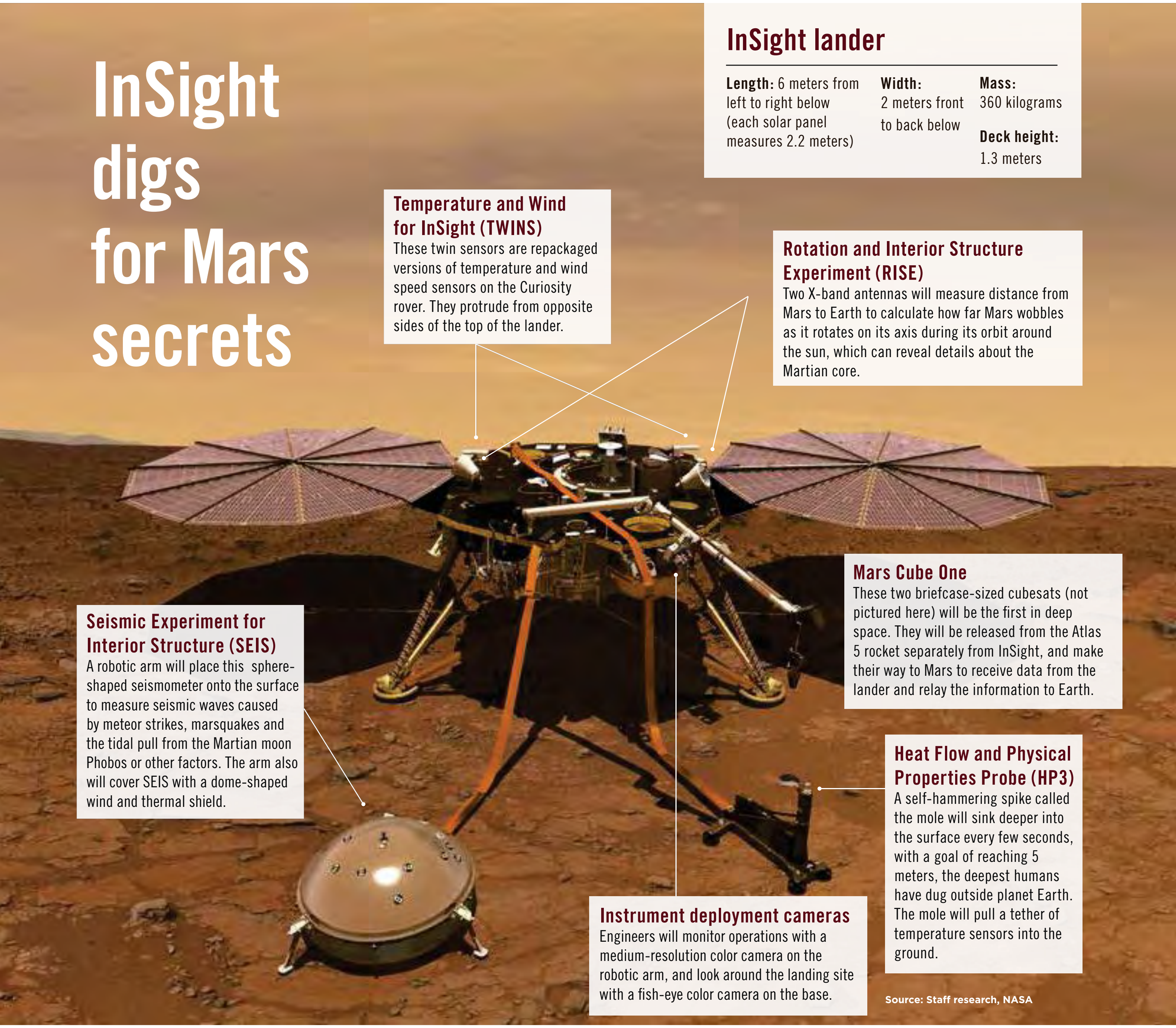
"The Japanese had trained for multicarrier task groups so the ships could reinforce each other," he says. "The Zero [Mitsubishi-built fighter plane] was unquestionably faster and more maneuverable than the Wildcat, but was also more vulnerable to gun fire."

The planes are a rare find and "tempting" to raise from the ocean, especially because there are no intact TBD Devastators on dry land, Burke says.

"The [U.S.] Navy still owns the planes and would have to give permission for recovery," he says. "I believe the depth also makes recovery extremely difficult."

Locating the wreckage is significant because it could now be designated as a war gravesite. ★

InSight digs for Mars secrets



The lander will measure heat beneath the planet's surface for answers about why its core cooled, unlike Earth's.

Scientists don't know why the core of Mars cooled, causing it to stop generating plate tectonics and the type of magnetic field that protects the atmosphere of Earth from being stripped away by solar winds. NASA theorizes that without that magnetic protection Mars lost its atmosphere and possibly oceans over the eons. NASA-funded Jet Propulsion Laboratory plans to launch a probe between May 5 and June 8 to land on Mars and take the first comprehensive measurements of the planet's interior that could determine how other rocky planets including Earth are formed. The InSight probe, which is short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, built by Lockheed Martin, will launch on an Atlas 5 rocket from Vandenberg Air Force Base in California on a six-month journey to the red planet. InSight aims to dig deeper into Mars than humans have ever dug on another world, so JPL chose a landing site that is relatively rock free. InSight is the first mission with the goal of measuring the heat flow within Mars, and the first deep space mission to be accompanied by orbiting cubesats. — *Tom Risen*

Warner Bros.

2001: Space futurism

Michael Benson chronicles the making of the Oscar-winning film 50 years later

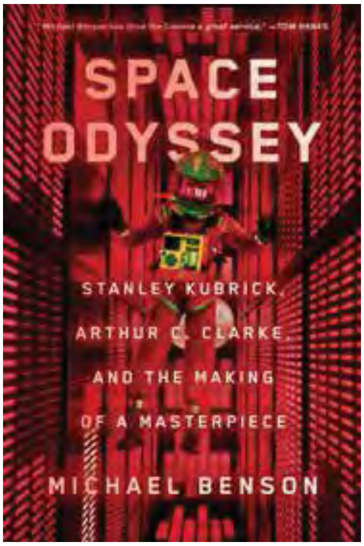
BY TOM RISEN | tomr@aiaa.org

Nations around the world are planning missions to the moon; businesses are meeting to discuss mining of deep space resources; and artificial intelligence is becoming a part of daily life. The Oscar-winning movie "2001: A Space Odyssey" is among the works of science fiction that inspired the age of space exploration that we live in today, and its filmmakers did so by brainstorming with space and technology visionaries before Apollo 11 had even landed the first humans on the moon.

Michael Benson, a filmmaker and author of several books about space, exhaustively researched the making of the 1968 cult classic for his new book "Space Odyssey: Stanley Kubrick, Arthur C. Clarke, and the Making of a Masterpiece." The book is due out in the U.S. and Canada in April to commemorate the film's 50th anniversary.

Benson richly describes how filmmaker Stanley Kubrick and novelist Arthur C. Clarke met in 1964 to co-write a movie about concepts including extraterrestrials, human exploration and the power of technology to both create and destroy.

Benson outlines the film's origin by drawing on candid photos from the film set, interviews with friends and colleagues of the late Kubrick and Clarke, including Kubrick's widow, and the men's personal journals. This saga also features encounters they had with icons in-



SPACE ODYSSEY: STANLEY KUBRICK, ARTHUR C. CLARKE, AND THE MAKING OF A MASTERPIECE

By Michael Benson
Simon & Schuster
$30 hardcover

▲ Keir Dullea in the role of Dr. Dave Bowman, the mission pilot and scientist aboard Discovery One in "2001: A Space Odyssey."

Actors Gary Lockwood and Keir Dullea flank author Arthur C. Clarke at a 1968 premiere of the movie.

cluding astrophysicist Carl Sagan and beat poet Allen Ginsberg, and other details that immerse readers in the zeitgeist of 1960s London and New York City.

The movie envisioned people from all nations living on the moon and space stations, albeit with Russians and Americans researching separately. Cold War rivalry between Russia and the U.S. was at its peak when the film debuted in 1968, and Kubrick was fresh off the success of his Oscar-nominated "Dr. Strangelove" about nuclear war. Americans in the film lead the fateful mission to Jupiter where the crew of the Discovery was sent to search for alien life with the spaceship's HAL-9000, an artificial intelligence character now synonymous with visions of a machine uprising.

Cinephiles will love details about the auteurs and stories of actors on the set, but these can sometimes overshadow examples in the 444-page book of the film's space futurism that inspired science fiction filmmakers including George Lucas and Stephen Spielberg.

Benson recounts how the smallest details in the film's sets, costumes and backstory were all made by Clarke and Kubrick with an eye for capturing how humanity's journey into space would shape society. The production team of "2001" included German-born designer Harry Lange, who had previously worked at NASA as the head of its "future projects" section, and Frederick Ordway, NASA's former chief of space information systems, who had helped develop the Saturn 5 rocket. Bell Labs, IBM and Hewlett Packard were among the tech firms that advised the filmmakers. The sentient supercomputer HAL-9000 was created with expertise from cryptologist I.J. Good and cognitive scientist Marvin Minsky.

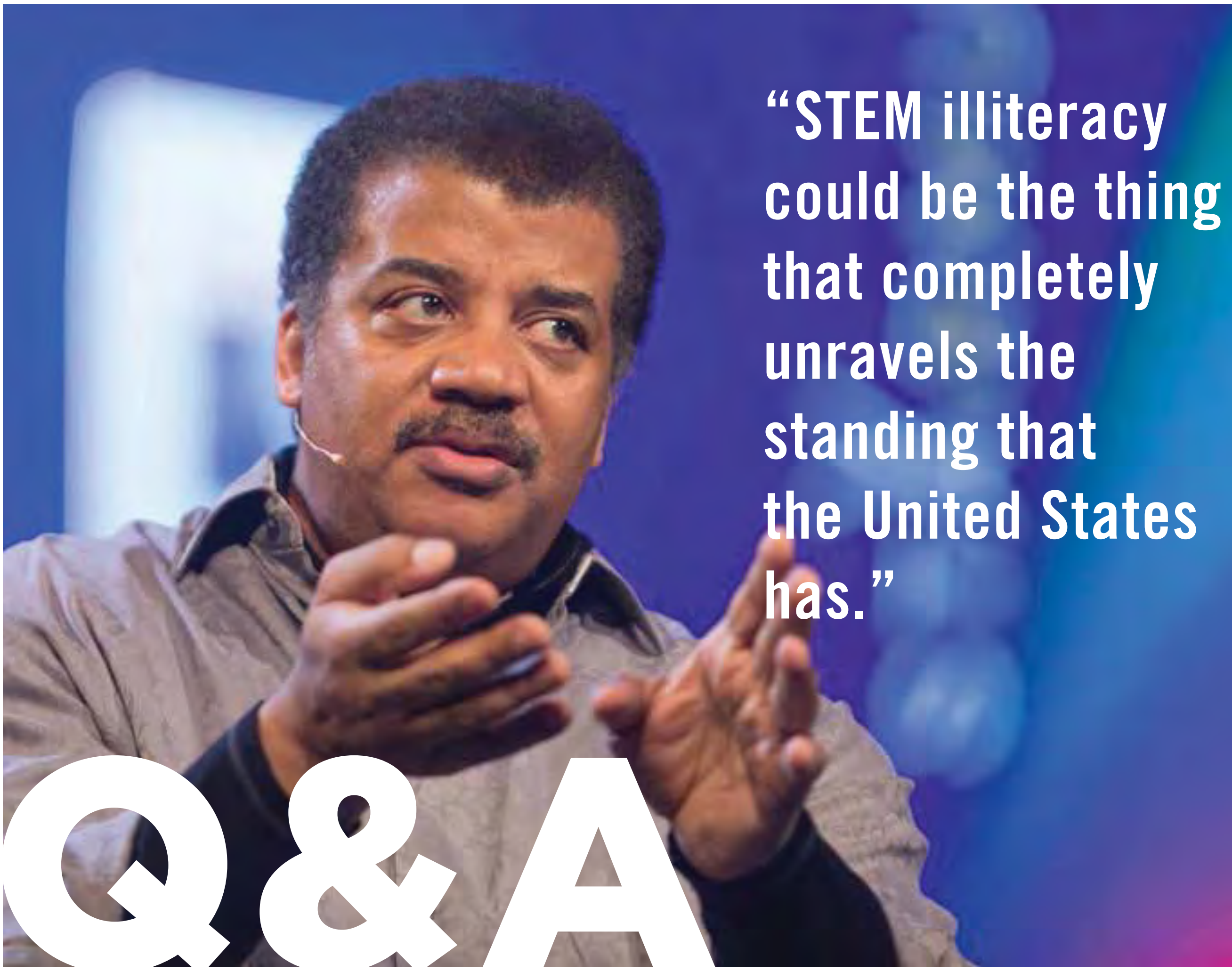
Kubrick created the illusion of microgravity with tricks including foreground sets locked to a camera that rotated as the backgrounds remained stationary, giving the illusion of a corridor spinning in space. To add context for Kubrick's ingenuity to simulate space travel, Benson's book has received advance praise from Hollywood veterans, including

Stanley Kubrick in 1968

Tom Hanks, who performed scenes in microgravity during "Apollo 13" by filming on NASA's KC-135 plane.

Benson's book made me realize that in the decades after the debut of "2001," life is not imitating art but it's not far off. Airliners are not ferrying people to a Hilton hotel on a space station that spins to maintain gravity but rocket company Blue Origin's Jeff Bezos has spoken about space tourism as a potential business model. There is no moon base, but efforts to send humans back to the moon are more international than Kubrick and Clarke dreamed of during the Cold War. Russia and the U.S. are collaborating on a Lunar Orbital Platform-Gateway space station for an orbit between Earth and the moon. The European Space Agency is also gathering international commitments to partner on a Moon Village, which is intended to be a research station on the lunar surface open to all nations.

NASA is also designing the Europa Clipper probe to orbit Jupiter and search for extraterrestrial life on the icy moon of Europa. The probe probably won't find a giant black monolith left by aliens or rebel against NASA like HAL-9000, but the mission will take humans on the next step of our space odyssey. ★



Science communicator

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Astrophysicist Neil deGrasse Tyson has emerged as an outspoken defender in the U.S. of science and its underlying processes, all of which he suggests are dangerously ignored in Congress and the White House these days. As frustrating as things can be, he says it is possible to discuss science without resorting to screaming. I spoke to Tyson on the phone about the Trump administration, the ethos of science and technology, our collective future and the next season of "Cosmos," his 21st-century update of the groundbreaking 1980 television documentary hosted by Carl Sagan.

— *Tom Risen*

NEIL DEGRASSE TYSON

POSITIONS: Host of "Cosmos" TV documentary and "Star Talk" podcast. Director of Hayden Planetarium in New York City since 1996. Staff scientist at Hayden Planetarium from 1994 to 1996.

NOTABLE: Director of the Hayden Planetarium during the reconstruction completed in 2000. In 2004, served on President George W. Bush's "Moon, Mars and Beyond" commission, which held public hearings and recommended priorities for NASA. Popularized the term "Manhattanhenge" in Natural History magazine to describe the solstice alignment of the sun with the street grid of Manhattan island.

AGE: 59

RESIDENCE: New York

EDUCATION: Bachelor's degree in physics from Harvard University; master's degree in astronomy from University of Texas at Austin; doctorate in astrophysics from Columbia University.

IN HIS WORDS

New episodes of "Cosmos"

It'll be the same spirit and the same DNA as the previous "Cosmos," as well as the "Cosmos" back in 1980. And that DNA is about what it is to be a participant in the ecosystem of the world, as opposed to being distinct and separate from it. We are trained to think of science in these stovepipes. You're a biologist, you're a chemist or you're a geologist and you have a show that covers all of them and it sounds like it's broad. But Earth doesn't care what you are when an asteroid comes. Ann Druyan, who is a sort of creative force of this show, is deeply scientifically literate and even more deeply enlightened with regard to the human condition. She was one of the original writers in 1980 [and later Carl Sagan's wife].

Scientists as expert commentators

If a bridge falls down, I'm not going to volunteer to be the person who comments on the structural failure of the metal members of the bridge. No, I would say go find an engineer for that. If there is a question that relates to the universe and my answer needs to tap the chemistry, geology, whatever, if that happens to be outside of my specific expertise, then I'll do some homework and brush up on that.

Scientists advocating in politics

Should scientists address members of Congress? I'm not going to say what they should or shouldn't. I will never tell someone what they should do. If I'm asked to testify, then I will. That's just you're doing a citizen duty. I'm not going to lobby Congress, because that means I'm telling Congress what they should do separate from what their electorate tells them what to do, and I'm not going to do that. I don't focus on elected officials because they are elected by an electorate. So if the lawmaker happens to not be scientifically literate, it means the people who voted that person into office are also either not scientifically literate, or they do not care that the person that represents them is scientifically literate or not.

Science education and democracy

You could talk yourself till you're blue in the face getting a [congressional] representative to think one way about science relative to another, and then they're up for re-election in two years. And somebody else comes in. Now you've got to do that again? Well, you can bypass that entire exercise and educate the public. That's what "Cosmos" does, that's what books do, that's what documentaries do, that's what I do. I say as an educator, I should train people what science is and how and why it works, and what are the consequences of actions and inactions. You can choose to not teach science in the school classroom, because education is local, it's not federal, because it's not mentioned in the Constitution, therefore, it is handed over to the states. You can teach Earth is flat and, OK; I'm not going to scream at you, I'm just not, I don't have the time or energy to do so. What I will say is, if you teach people that Earth is flat, you are disenfranchising your community, your state, from any future industry moving their factory or their headquarters into your community. Because the growth industries of this world are all tech-driven, science-driven, engineering-driven. And if you care about wealth and health and security, then you better start becoming STEM literate so that you can make informed decisions regarding it, including decisions regarding who represents you, not only in municipal government but in federal government. And so if you choose not to, then you will bankrupt your state.

Nomination of Rep. Jim Bridenstine, R-Okla., for NASA administrator

What's interesting to me is not what he has said in the past, but is he capable of learning things he did not know in the past, and what knowledge will he be taking forward into that job? That's what educators do, we try to enlighten people. If he says, I'm sticking to my guns, I'm incapable of seeing what the scientists are saying, if he then becomes head of NASA, and then implements the direction of NASA in consort with those ideas, then NASA will fade on the world stage of space exploration. Other countries who do understand what science is and how and why it works will pass us by, like Russia, India, especially China. We can sit here and debate climate change forever, go right ahead, just don't expect the United States to lead the world in anything going forward.

Republicans and climate science

Not only is it the Environmental Protection Agency that banned lead in paints and other things under a Republican president, it was the EPA that was created under a Republican president, President [Richard] Nixon. And when the EPA came online there was a Clean Air Act, the Clean Water Act. If you're a Republican and you're denying human-caused climate change, that's odd to me, because you'd have to then be denying science. And there's a lot of other science that they do not deny, like quantum physics, which is responsible for the computers and the cellphones they use. What I think is really going on is, they don't want any legislation related to curtailing climate change to negatively influence their investment portfolio or the industries that people think would get hurt, hurt as in economically hurt by such legislation. What should happen is they should say, "Oh, we recognize the science, we just don't care. I care more about the money I'm going to make in the next six months than the effect that this will have on the environment in five years or 10 years." At that point it's pure politics and money, rather than science.

Targeting of environmental science

[President Donald Trump] doesn't talk much about science at all. So it's very hard to link any specific policy being implemented on anything. We have representative government. You never had episodes of people debating what science was true or not, when it came time to think intelligently about legislation. So it means that people who voted for Trump, they either know about the science and don't care, or they don't know about the science. So you get the country you voted for in a democracy. If the nation does not embrace STEM, it will cost us economically, it'll cost us with regard to our health, it'll cost us with regard to our security.

New York and flood risks of climate change

It seems like people are more able and interested in spending 10 times as much money to rebuild as they are to prevent themselves from having to rebuild in the first place. You say, "Let's build a higher flood wall, we've never had a flood that high before."

And then a flood that never happened before happens and takes out half the city. It may be unique to America, but it's probably something human. We're not good at being pre-emptive about things that we don't physically see or experience. So the countries that have such foresight, that do make such investment are the ones that will assure their survival and their continuance on the other side of that catastrophe. STEM illiteracy could be the thing that completely unravels the standing that the United States has come to build and enjoy out of the 20th century.

Engineers in astrophysics

The last thing you should tell an engineer is "design this however you want and here's an unlimited budget." But if you say, "it's got to be under 30 kilograms and it's got to happen within this budget and it's got to be done within this amount of time," then extraordinary creativity unfolds. In my field, we depend heavily on innovative engineers. For example, how do you put a telescope mirror that's bigger than the diameter of a fairing, on a launch fairing of a rocket? They figured out how to unfurl a mirror, and then, boom, you've got a mirror bigger than the fairing. I still deeply enjoy doing original research, it's just hard to fold that into the rest of my activities, so much of which are trying to enhance public appreciation for science through books and radio and TV and the like. But I have this fantasy that one day I give it all up and just go back to the lab.

Challenges, opportunities for science careers

Today there are more opportunities to be an astrophysicist outside of academia. There's an entire space industry, for example. You can be an astrophysicist for Lockheed Martin or for Boeing or for Northrop Grumman. You can work for NASA in multiple ways in many of their centers at JPL and Goddard in Maryland, for example. Possibly even SpaceX or for Bigelow. They all need astro folks who are trained in physics, who think about the universe, who know how to code. So it's not different from when I was growing up in the sense that the path of study is the same. The physics, the math, the rigor, the focus, the intensity, the commitment, especially. What you do with it afterward is just a matter where your interests fall. Do you want to stay in academia, do you want to go out to industry? The only other difference is today, there are many more occasions for a person to bring the universe to the public.

Diversity in hiring and advancement in aerospace

Advancement is different from hiring, of course. I'm not close enough to that world to have insight into how well it's doing or not. There were some very powerful women in the aerospace industry in the past, but the fact that I can name them means there weren't many of them. Joanne Maguire [former executive vice president at Lockheed Martin], for example, was very powerful, highly influential and there's also the WIA, Women in Aerospace. That's a very well-organized community of women in the field and they would surely have statistics on this. I just don't know.

Doing science for defense contractors

I'm not one to judge their ethical compass on this. I can say that some fraction of us do exactly this: They go into an industry and will participate in classified research in the service of the defense of the country. Less than 10 percent do so, but they do and they are paid way better than you are if you stay in academia. That's also true just for going to industry at all, that's the allure of industry. They'll pay you at least 50 percent again of what you would get paid if you stayed being an academic scientist. The best of the managers are the ones who understand the mindset of a STEM professional when it's time to manage them and inspire them and to make the right decisions going forward.

Coexisting parallel universes, a multiverse?

In a multiverse there's an unlimited number of universes, all with slightly different laws of physics, in the model that we're thinking about today. There's good theoretical justification to think that way [because of] quantum fluctuations in the early universe. We create bubbles, each bubble will then have its own laws of physics that would expand, contract, so we'd be in one such bubble.

College of DuPage

Neil deGrasse Tyson says there are more opportunites for STEM careers now than when he was a youth. High school students investigate careers in the science, technology, engineering and math fields with hands-on activities at a community college.

"Today there are more opportunities to be an astrophysicist outside of academia. There's an entire space industry. ... They all need astro folks."

Studying the Big Bang

Right now we can see 380,000 years after the Big Bang, using electromagnetic-wave telescopes. However, neutrino telescopes, gravitational-wave telescopes, can pierce that wall, and enable us to see much farther back in time to the first fractions of a second, after the explosion. The LIGO [pronounced lie-go, the Laser Interferometer Gravitational-Wave Observatory] gravitational light telescopes in Louisiana and in Washington state detect gravity waves, and there's several others being built around the world. Those get even more sensitive and better designed, then we can part that curtain and see even before [the Big Bang]. We have ideas of what happened before, but it'd be nice to get first-hand evidence.

Risks of artificial intelligence

All technologies have dangers. I don't see the future of AI in that role being fundamentally different from challenges we've had to face in the past. There's the concern that AI just will get up and say, "Oh, we don't need humans; humans are a scourge of the world." I'm glad science fiction writers are portraying those futures. It means these are futures we will know we don't want, and then put in protections for us. Will AI make us more lazy than television has? With television you have to sit there and do nothing else. If instead, you are in some kind of virtual simulator and you're spending 30 hours a week on that, I think the net effect is the same.

Autonomous flight

We are already deeply embedded in AI. The Boeing 777 airplane is flown by computers [pilots say much of the time]. We have contained the kinds of decisions they make for very specific roles. I see the future of AI as being very tuned to specific needs of our lives. That's been the trend and I don't see why that wouldn't continue.

Government search for alien life

I think in the next 50 years we will know whether or not there's any life at all on Mars or Europa or any other places in the solar system. So, SETI [the search for intelligent life] is a small percent of the total money spent on astrophysics. It's completely sensible that some fraction of any total research budget goes into a very-low-probability, but high-impact discovery. I think if you interviewed the community of astrophysicists, we're all perfectly happy that some amount of money goes into that exploit. I'd want the Pentagon to look at things that might be a security risk. And if an F-18A infrared sensor finds something we don't understand, I'd hope they'd be checking it out. As for eyewitness testimony of pilots, this is a very low form of evidence in science.

Is Earth ready for alien visitors?

There is no day where I think we would be ready, it'll just happen and we'll all freak out, but then we'll get used to it. If we meet them, it means they came to us, which means they're light years ahead of us in technology.

Nuclear weapons: spiritual vs. scientific power

The 20th century didn't invent war. Every generation since we were hunter-gatherers, a smaller and smaller percentage of people have died at the hands of an enemy force, even into the 20th century. So in other words, if you're a tribe of 100 people, let's say, and you have a watering hole and there's another tribe that wants to fight you for the watering hole, a third of that 100 people could end up dead. There are some countries that were small where a third of the people died in the Second World War, but when you take the war in total, no, that's not what happened. As much as we ran ramshackle over Germany, the fraction of Germany's population that died in the war is smaller than that of hunter-gatherers. And by the way, why is a nuke somehow spiritually different than a missile that doesn't have a nuke? To say today we have a nuclear warhead and so [our scientific power has outrun our spiritual power] is missing the actual likelihood of you dying in warfare.

Astronaut gene editing

We will have very high control over our genome in the not-so-distant future. If there's some feature that we need to adjust, the spacefarers would get their genes adjusted and then they'd go into space. I don't see adjusting DNA because you want to be a spacefarer as a moral issue. I don't see that as any different, really, from what anybody else is already doing with their lives. We make changes to our bodies that don't involve DNA adjustment. For example, if you're an Olympic competitor, your body is really different from everybody else's, and it didn't happen genetically, it happened because you trained 40 hours a week.

Artificial-gravity spaceships

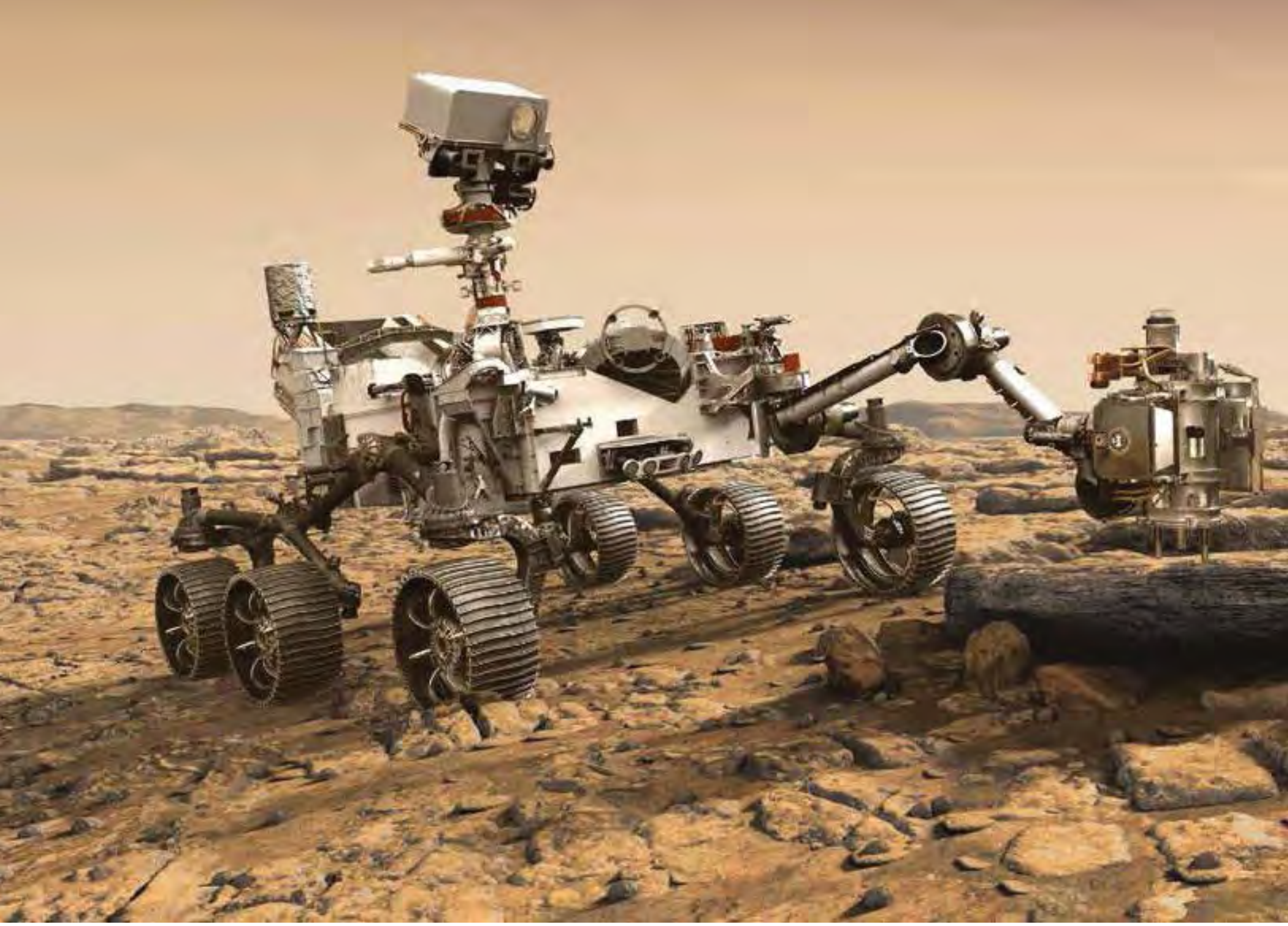
The concern about zero gravity is then you design a spaceship that spins up, and then you have artificial gravity. It's solvable instantly and not enough research has been put into that, basically. So if you go on any real long space journey, just design something that rotates. Reality seems to be behind science fiction in that regard.

Hibernation in deep space

I don't see it as a priority. There is no meaningful talk of suspended animation for space travel. In science fiction stories the premise is we would go into hibernation. The questions you have to ask are how much are you saving? And do people who had spent time in the suspended animation, do they live longer? If you look at mammals that hibernate, you know their heart rate drops and their metabolism slows down. So you have to ask, "Why would we want to do this? Is it to save food?" [If] you're not going to die later than you'd otherwise die, it's really just to save food. But really, is food the heaviest thing you're worried about on this trip? If we're traveling in the solar system, then it's five years here, 10 years there. But so what? Just go get a movie account or something, and bring books.

Private space missions to Mars, moon

None of this is going to happen unless there's an economic return for it. It's not going to happen because we want to do it. This was a big mistake we all made in the 1960s: "Oh we're on the moon in the 1960s, yeah we'll be on Mars by 1985, and we'll have colonies." We went to the moon because [the Cold War] took us there. In a free democracy, a capitalist democracy, there's two reasons why we would do anything that's supremely expensive: One of them is because we don't want to die, that would be a war driver, and the other is we can get filthy rich, that's the economic driver. If neither of those two are satisfied, I just simply don't see it happening. ★



For Mars 2020, circuitry is a key

NASA's Mars rovers have always posed fascinating power and circuitry challenges, and so it is with the Mars 2020 rover now in assembly at the NASA-funded Jet Propulsion Lab in California. Dale McKeeby of California-based Pioneer Circuits explains the rover's innovative circuitry scheme.

BY DALE MCKEEBY

NASA

▲ **This is an artist's rendering of the Mars 2020 rover,** which is being assembled at NASA's Jet Propulsion Lab in California.

Our staff here at Pioneer Circuits began working on Mars rovers in 1994 when we received a request from NASA's Jet Propulsion Lab in California to build circuitry for an upcoming mission now known as Mars Pathfinder. The mission's 10.6-kilogram rover, called Sojourner, was the first ever on the Martian surface, but when we joined the project, JPL thought mass limits would rule out a rover in favor of a stationary lander. The problem was the weight of the hard wiring necessary to deliver power to the rover's electronics, including its visual system and the high gain antenna for communications between the rover and the Deep Space Network antennas on Earth. Analysis showed this wiring would weigh 0.7 kilograms — enough to make the rover oversized and overweight.

Pioneer took on the challenge and built a 30-layer flexible printed wiring board, PWB, that replaced all of the hard wiring and reduced the weight to only 87 grams. This multilayer rigid flex PWB construction provided a conduit for communicating data, including telemetry for guidance control and video, while simultaneously supplying electrical power to components. What made the circuitry special was not its constituent components of copper-clad, polyimide film and acrylic adhesive. Rather, it was the manufacturing process. We devised a composite process in which individual sublaminates were bonded together with heat, pressure and adhesives. Our challenge was the structural instability of the base material, which made the part inherently difficult to laminate. We devised tooling that compensated for this inherent instability. Instead of wires, electricity flowed through different circuits in the same rigid board construction through which data was routed. The construction of this PWB is a composite of rigid and flexible circuits that cross from one rigid section to the next with flexible circuit interface. This way, the assembly could be bent to interconnect all of the rover's communications, telemetry and visual modules.

The little rover, which would have been considered a success if it had lasted only 1 sol or Martian day (about 24 hours and 37 minutes), ended up lasting 90, giving credibility to flexible circuitry for Mars rover applications.

Our contribution to the success of the Mars Pathfinder rover positioned Pioneer as a partner with NASA's Jet Propulsion Lab for many more robotic discoveries across the red planet, including the Opportunity, Spirit, Curiosity and now, the Mars 2020. This new rover, in assembly at JPL, will weigh in at 1,050 kilograms and measure about the length of a sedan, not including its robotic arm. Its design posed familiar power and circuitry challenges, but in much larger amounts. Mars 2020 must extend its 2-meter-long arm to gather pellet-like core samples of Martian soil and rock with a drill, and take pictures of the samples. Overall, the rover will have 23 cameras compared to Curiosity's 17. Specifically, a mostly titanium mast will rise from its chassis holding Mastcam-Z, a collection of cameras for zooming in on terrain, taking 3-D pictures and panoramic shots.

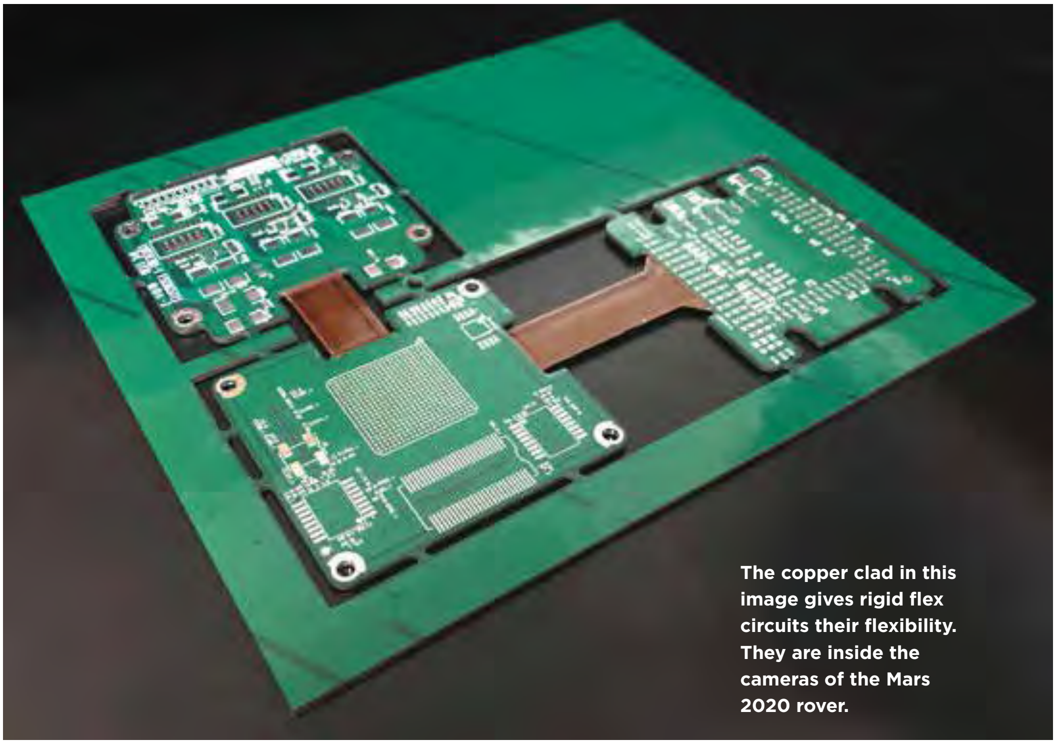
These devices will need to receive power from the rover's two batteries, and commands from the rover's brain consisting of two Rover Compute Elements. Images must also flow back to the brain for navigation and for transmission to Earth. The circuitry for this must withstand the extreme temperatures of the Martian environment, and the circuitry must be flexible given that the rover will roll across rugged terrain, fold its mast into its upright position and extend its arm to drill samples.

The mast was a special challenge. It must be folded down during landing and will then fold up to properly position Mastcam-Z about 1.5 meters over the rover's chassis. To deliver power and create a data pathway to Mastcam-Z, we chose an Extended Length Flex Cable similar to those on Curiosity, Spirit and Opportunity. We developed this technology about 20 years ago and tested it with JPL. At the time, we had just learned that the Opportunity and Spirit rovers required a never-before-seen 2.13-meter-long, four-layer, shielded flex circuit to connect all internal electronics, providing the rovers with control, communications and video signal to Earth. To create such a long cable, we devised a proprietary technique for splicing together long flex circuits consisting of polyimide 0.002 mil-thick film and copper-clad sheets. Our splice technology ensures flexibility between the joints via a unique stress relieving technique we developed. We applied this technology to Mars 2020, which needs flex circuits of up to 10.66 meters. Also, because the components of the Mars 2020 rover were more complicated, we needed to condense even more power into these circuits.

The reliability of this "splice" technology and the extended length flex has surpassed even the most optimistic projections. The life span of Opportunity, for instance, was predicted to be 90 days, and as we all know, Opportunity is still generating pictures and scientific data from the Martian surface today.

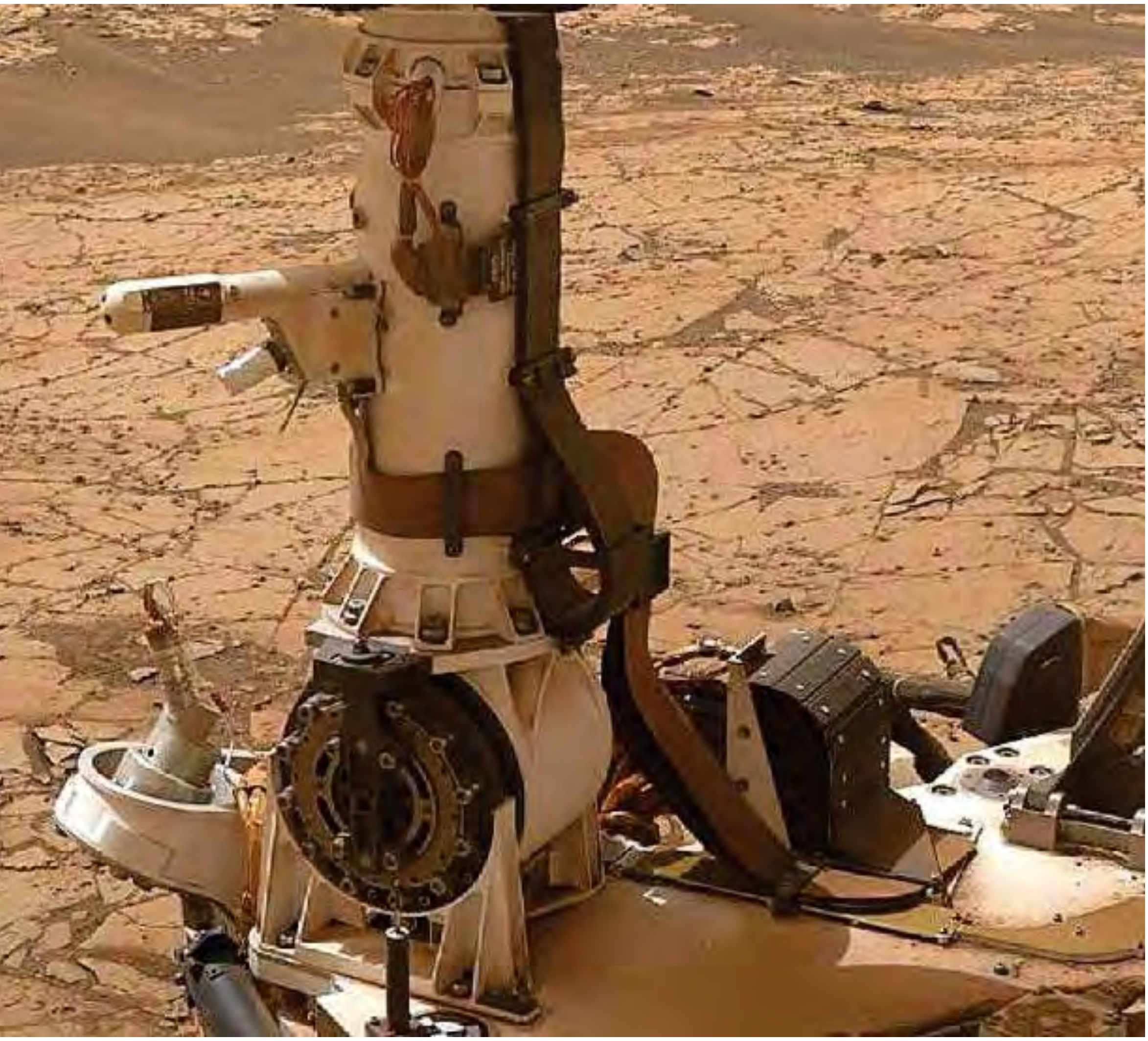
Mars 2020 posed a unique challenge for our splice flex circuits. These must deliver electricity from the rover's two batteries to its electronics, including the 23 cameras, and also provide data pathways to help the rover navigate, avoid hazards and take images of samples. The large number of cameras meant we had to increase the layer count for the flex from four to six to connect such complex modules. With the splice technology. I worked closely with the JPL team, when they brought a mock-up of the mast

▲ Pioneer Circuits tested its latest flexible circuitry on this mock-up of the Mars 2020 rover's mast.
NASA



The copper clad in this image gives rigid flex circuits their flexibility. They are inside the cameras of the Mars 2020 rover.

Pioneer Circuits



This image taken by the Curiosity rover on the Martian surface shows the extended length flex flight part (brown, flat cable that starts on deck and wraps around the mast) that powers the camera and the rest of the rover.
NASA

here to our facilities, to make sure the upgrades to the flex circuit would work and be just as reliable for the Mars 2020 rover.

Also, the electronics inside these cameras utilize rigid flex circuits, which combine the durability of rigid circuits with the reliability and flexibility of flex circuits. The main objectives of using flex and rigid flex circuits was to overcome space and weight confinements as well as to improve reliability as we did for the original Mars Pathfinder Sojourner rover. Back during development of the other rovers, I recall sitting in a NASA board meeting with JPL where different project managers were answering questions. One key question was what percentage of hard wiring on the rovers after Sojourner could be replaced by flex circuits. The answer to this was 17 to 20 percent, which satisfied the NASA question. This meeting laid a strong foundation and path forward for the JPL team and me to work on the rigid flex parts for future rovers.

For Mars 2020, we relied on mock-ups to develop the tightest and most robust configurations that would also have the highest reliability. I provided open communication with the JPL team, providing weekly updates and sharing challenges of the different configurations along the way. JPL then pulled up original design drawings from previous rovers and worked with us to update it for the new configuration.

The rover's human-like arm will have a Force Torque Sensor to detect the forces applied to the arm to give the robot feedback and help it be flexible and adaptable in its movements. Several companies including JPL and Motiv Space Systems came to Pioneer for help with multilayer flex circuit manufacturing as well as the difficult final assembly. The arm's newly developed, multilayer flexible circuit package provides for finer torque control. In fact, the Force Torque Sensor system is the most complex flex circuit assembly ever integrated into a Mars rover arm.

Overall, Mars 2020 adds to the list of flexible circuit technologies that power the capabilities of Mars rovers. ★

Dale McKeeby, vice president of engineering at Pioneer Circuits of Santa Ana, California. He joined the company in 1991 and now leads research and development, concurrent engineering, and prototype manufacturing for the Deep Space sector. Pioneer's other business sectors are military applications, satellites and avionics. Email info@pioneercircuits.com

Wanted: a realistic moon plan

The Trump administration wants to return Americans to the moon, first in orbit, followed by expeditions to the surface. Questions abound about the plan's feasibility. Astronaut and planetary scientist **Tom Jones** offers advice for avoiding a third failed attempt to get Americans back to our celestial neighbor.

BY TOM JONES | www.AstronautTomJones.com

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In announcing the Trump administration's strategy for returning to the moon, Acting NASA Administrator Robert Lightfoot told an audience in Huntsville, Alabama, that the agency would work with contractors to construct a minimalist outpost near the moon to support astronauts on annual visits of increasing duration, while serving as a tech lab and transportation hub for eventual sorties to the surface. My sense is that this outpost may eventually evolve into a 2030s "dockyard" for building a piloted ship headed for Mars.

NASA says it knows how to build this Lunar Orbital Platform-Gateway or LOP-G (Memo to NASA: Find a better name). Assembly in space would begin in 2023 when a Space Launch System rocket lifts off carrying the first Orion spacecraft with a crew aboard. NASA also says it knows what astronauts will do during successive visits: conduct lunar observations, control surface rovers and test exploration equipment. What isn't so clear is how this return-to-the-moon venture will succeed where two previous NASA efforts have failed to launch. I'm not at all certain that the Trump administration has committed to delivering the required funds and political support NASA will need for our return to the moon.

Achilles' heel: Funding

The lunar gateway's purpose will be to enable human explorers to test life support and critical deep

▶ Commercially built lunar landers, like Blue Origin's Blue Moon, may take NASA scientific and resource payloads to the moon in the early 2020s. Proven lander designs should help NASA produce a human-rated ship for lunar landings in the late 2020s.

Blue Origin

◀ The footprints of astronauts Neil Armstrong and Buzz Aldrin are visible in the dust around the United States flag they planted on the moon's surface on July 20, 1969. It remains to be seen whether NASA will have the financial and political support to return Americans to the moon.

NASA

space systems in the harsher environment beyond low Earth orbit. When Vice President Mike Pence promised in October 2017 “a renewed American presence on the moon,” NASA refocused its planning for this outpost from an orbital way station to a gateway both to the nearby lunar surface and deep space — namely, Mars.

NASA hopes subsequent Trump administration budgets will enable steady expansion of the gateway and periodic crew visits of a month or more. Crews would ride on NASA’s Space Launch System rocket, and supplies would be rocketed to lunar orbit by international partners or, more likely, by firms including SpaceX, Boeing and Blue Origin.

Meanwhile, robots will establish routine access to the moon’s surface, renewing scientific studies, prospecting for resources, and scouting habitat locations. As the moon campaign hits full stride, astronauts would venture to the surface in the late 2020s.

The lunar campaign’s Achilles’ heel will always be miserly funding. NASA predicts it will cost about $2.7 billion over five years to mount a Lunar Exploration Campaign and see the initial launch of the gateway. Yet the administration’s proposed 2019 NASA budget contains just a slight increase — to $19.9 billion — followed by another four years of flat spending. To find money for the moon, NASA has been told to shuffle funds away from space and Earth science, and the International Space Station, redirecting them toward the lunar campaign.

That’s a tall order. Congress will likely reject these priority shifts, leaving the lunar program underfunded. NASA may be able to pay for a few test flights of Orion and the Space Launch System, but it won’t be able to afford robotic landers and a human-tended lunar outpost, let alone build a piloted lunar module. NASA’s top line budget must increase, or we will still be looking at the moon from afar as the ISS plunges into the Pacific after 2028, the projected engineering “drop dead” date for the station. Time to write your congressman.

Sunsetting ISS

No feature of the administration’s NASA budget has drawn more controversy than its proposal to terminate government ISS funding by 2025. Shifting station operations to the commercial sector by then could free up $3 billion annually in subsequent years for lunar exploration.

Setting a firm date for this transition is a gambit to force NASA to start easing ISS toward a private operator, while NASA would remain a research customer for tests of key deep-space technologies, such as a new spacesuit, life support systems, and biomedical countermeasures against radiation and free-fall deconditioning. But the process will be neither simple nor quick.

Congress will not allow a flat-out giveaway of a multibillion-dollar government asset to the private sector. Nor can NASA hand over ISS modules owned by our international partners.

This creates a conundrum. NASA needs ISS to be available beyond 2024 to prove the technologies for inhabiting deep space. But it also needs additional funds for building up lunar operations. The president and Congress must fund critical ISS research even as they direct a growing presence around the moon. The reality is that NASA’s top line budget must increase. A 5 percent boost to about $21 billion is the minimum investment needed. That’s less than half a percent of the overall federal budget. Want the moon? Pay for it.

Don’t lose the moon

Funding alone won’t guarantee a return to the moon. Here are some additional steps NASA should take:

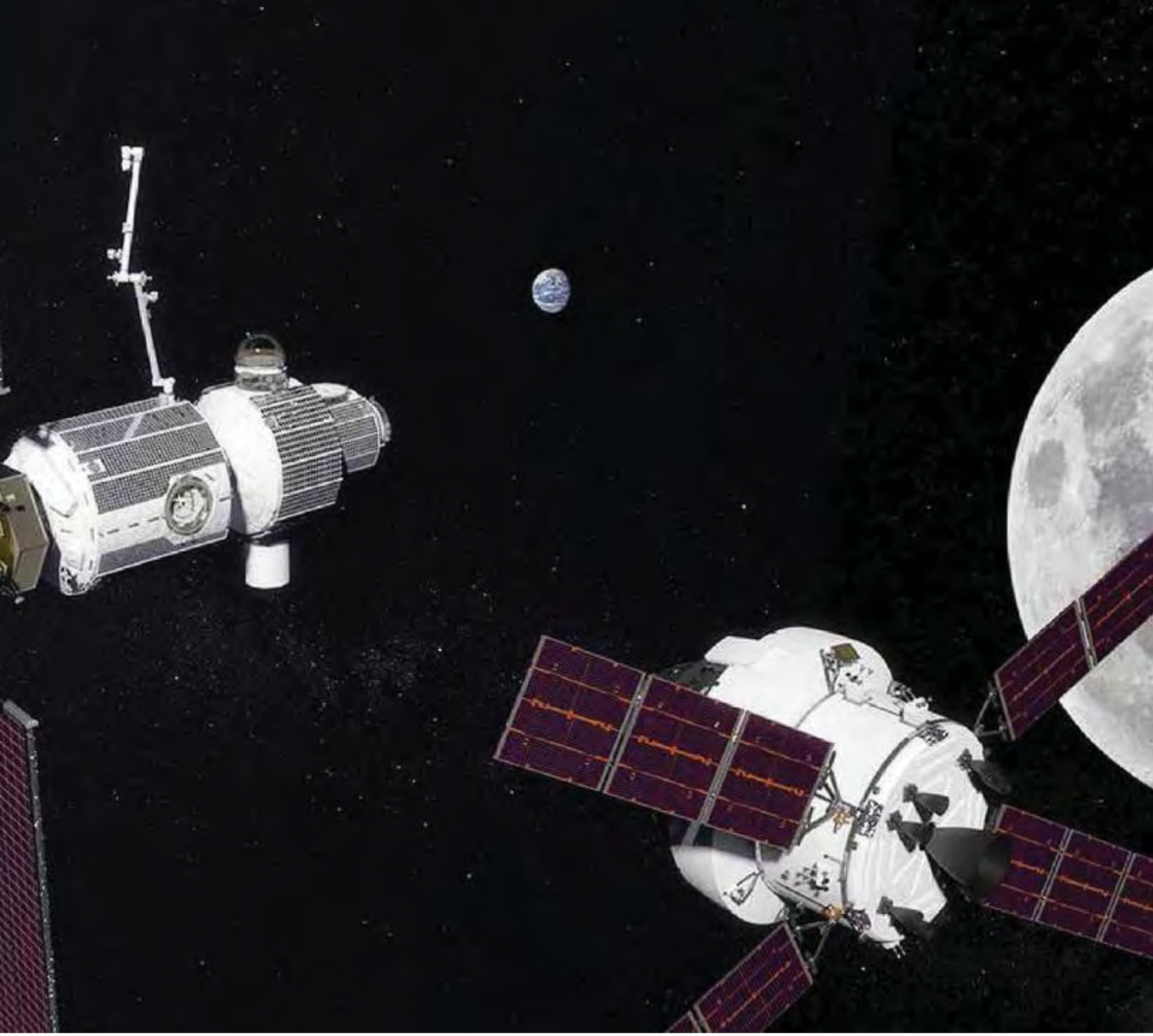
Don’t low-ball the resources needed. The misfires of the Space Exploration Initiative in the 1990s and the Constellation Program in the 2000s were partially due to unrealistic budgeting — too high in the case of the Space Launch Initiative and too low in the case of Constellation. NASA should tell Congress and the public what it will cost to return to the moon, and if voted those resources, perform within that budget.

Negotiate with our ISS international partners to collaborate around the moon, but be leery of putting any one partner in the critical path to establishing the lunar gateway. We learned in the ISS program the costs of assigning critical hardware elements to cash-strapped (and an increasingly adversarial) Russia.

Don’t buy a lunar lander the way NASA has always done such things — by hiring contractors to meet detailed and unprecedented specifications. Ask industry to evolve commercial designs, like Blue Origin’s robotic Blue Moon lander, toward a piloted vehicle. Human access to the moon’s surface should be a competition-driven service, rather than an expensive, government-run transport monopoly.

Finally, put human explorers at the center of the moon story. Use the unique skills of astronauts to tackle the deepest scientific mysteries of the moon. Put them to work building and maintaining optical and radio telescopes on the moon’s far side. Follow up robotic discoveries to have astronauts tap the richest water ice deposits on the moon. Assign them to establish pilot plants that turn that ice into rocket propellant, paving the way for a profit-driven resource economy on the moon. Show how astronaut habitats, power supplies, rovers and spacesuits will provide the experience needed to deploy those same systems to Mars.


NASA



▲ **This artist's rendering shows NASA's proposed Lunar Orbital Platform-Gateway,** which would test hardware for future trips to the moon and Mars.

A meaningful step toward Mars

For the last 10 years NASA has had the luxury of talking about humans on Mars without doing much to make it a reality. Now, the agency has been told to prove it can reach the moon. To do so, NASA must overcome bureaucratic ossification, congressional indifference, defenders of the status quo, and an ever-shortening national attention span.

But there are reasons for optimism. New commercial space firms can develop innovative spacecraft designs and affordable launch and logistics services. SpaceX's launch of the Falcon Heavy in February is a good example of impressive industry capabilities unavailable to the NASA of the 1990s-2000s. Enlisting the commercial sector to tap lunar and asteroid resources might be the key to make deep space a realm where humans can stay.

The move toward the moon can happen quickly — politicians and the public might stay interested long enough to let humans again explore a world we've scarcely touched. A decade of experience on and around the moon can give NASA and its partners the technological maturity to reduce the risk of Mars expeditions and lower their costs to acceptable levels.

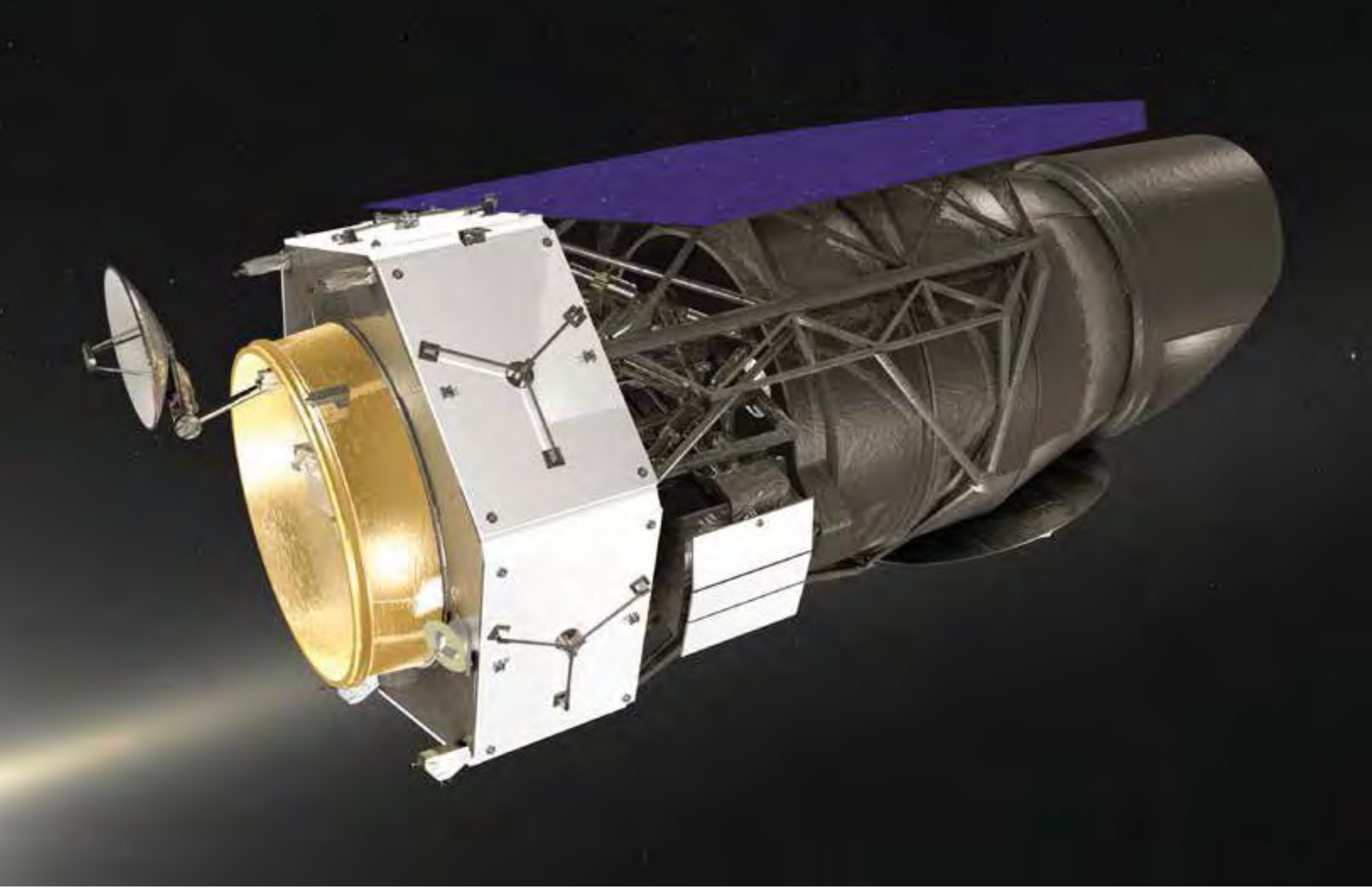
The moon offers America a chance to show it is still a rising technological power, willing to put its explorers at the cutting edge of scientific, engineering and economic frontiers. Given the national will and adequate resources, NASA and its partners can do the job. The moon is still there — let's go. ★

The case for WFIRST

Overlayed on a rendering of deep space, the white box shows Hubble Space Telescope's field of view compared to that of WFIRST, shown by the blue lines.

The Trump budget would cancel development of the Wide Field Infrared Survey Telescope, a spacecraft that would help measure the amount of dark energy in the universe while giving scientists a better sense of its properties and possibly delivering images of exoplanets, albeit giant gaseous ones at best. Is the proposed cancellation punishment for past sins on other projects? Will it be another close call for a project that's been on the brink before? Amanda Miller spoke to the scientists who could be asked to make the case for WFIRST as Congress weighs its future.

BY AMANDA MILLER | agmiller@outlook.com



NASA

▲ **An artist's rendering** of the Wide Field Infrared Survey Telescope.

If you love astronomy, you probably have some questions right now. Are the most thrilling aspects of space science about to get delayed by a decade or more? Why shut down the American astronomy community's top spacecraft priority, which would target the biggest astrophysical mystery known to humans?

At this point, you figure it's all about the money. NASA wants to get astronauts back to the moon.

But maybe it's not so simple.

If you're one of those working on NASA's Wide Field Infrared Survey Telescope, you're starting to sense additional reasons why the White House wants to end development of the spacecraft, even though the $3.2 billion program is pretty much on budget and WFIRST shows all the scientific promise it did when you went to work on it going on a decade ago.

"I think in some ways this may be OMB" — as in the White House Office of Management and Budget — "and others trying to punish the astronomy community for [past] overruns," says astrophysicist David Spergel of Princeton University, co-lead investigator for WFIRST, scheduled to launch in the mid-2020s. He's referring to President Donald Trump's budget request, now over to Congress, with a proposal to zero out funding for WFIRST in fiscal 2019.

"I think that some people have been saying that the cost has gotten out of control, and I think we're actually doing a pretty good job," says Spergel, one of the scientists who was anticipating pitching the project's virtues to congressional funding committees.

Scientifically speaking, NASA's three forthcoming space telescopes are meant to piece together a few different puzzles. Cutting out WFIRST would leave gaps in calculating the numbers and types of planets in the galaxy and decloaking the preponderance and properties of "dark energy," a theorized phenomenon or force that seems to be making the universe fly apart faster and faster. Also halted would be an optical demonstration of a technique that could, on a more powerful telescope in the future, give humanity its first image of an Earth-like planet.

International partners contributing hardware, technology and research are nervous that their investments could come to naught. Spergel has been giving "civics lessons" to explain that "just because the president's budget says it's canceled doesn't mean it's canceled." The president's budget is a request to Congress that never "gets accepted as is, and they shouldn't drop out and panic yet."

As the science team and NASA got ready to brief their oversight committees in Washington, I spoke to the astrophysicists who may be called on to explain WFIRST.

Biggest mystery in the universe

The Hubble Space Telescope's observations of distant-past supernovae led to a startling announcement in 1998. Astrophysicists said a substance, or phenomenon, or repulsive force of some kind must be causing the universe to expand at an accelerating rate, and that this dark energy must make up most of the universe. In fact, with today's observations, they estimate that dark energy makes up 68 percent. Scientists think that another 27 percent of the universe consists of "dark matter," a term coined decades before the Hubble discovery to explain why galaxies rotate as though they are heavier than suggested by their emitted light. The remaining 5 percent is the normal matter that we can see or detect.

Adding to the dark energy mystery is Einstein's theory of general relativity, which says gravity ought to be slowing the expansion. "Is this cosmic acceleration due to a strange, previously unknown 'dark energy' that is defeating the pull of gravity on the vast scale of the universe, or is it possible that we have discovered that Einstein's formulation of the law of gravity is not quite right?" That's the question posed in the 2010 decadal survey of astronomy and astrophysics priorities conducted by the National Research Council, an arm of the U.S. National Academies of Sciences, Engineering and Medicine. The survey listed WFIRST as the country's recommended "highest priority" space mission for astronomy and astrophysics.

WFIRST's cosmology experiments are meant to target this question about Einstein's theory. Scientists will measure the brightness of supernovae and the distortions in how galaxies appear caused by intervening dark matter. "These are all techniques used to try to understand how much dark energy there is in the universe and what its properties are," says Paul Hertz, director of NASA's Astrophysics Division in the Science Mission Directorate. "Because dark energy is so weak, it has such small effects, you have to study large numbers of galaxies and clusters of galaxies in order to accumulate enough statistics to do something measurable. So that's why WFIRST is so sensitive and has, compared to Hubble, such a large field of view."

In fact, WFIRST's field of view is 100 times larger than Hubble's.

Eight years ago, when WFIRST emerged as the highest priority, plans called for a 1.5-meter-wide mirror, but the science case grew less compelling as the European Space Agency continued developing its Euclid spacecraft to investigate the "dark universe" of dark energy and dark matter with a 1.2-meter mirror. Everything changed in 2011, when the National Reconnaissance Office gave NASA a 2.4-meter-wide mirror among telescope hardware that no longer fit within the scope of that agency's missions. Better resolution — and the prospect of adding another instrument — put WFIRST back on the table.

"It really enabled us to be a much more capable mission," Spergel says. "It also made it a very powerful successor to Hubble." The mirror is being retrofitted to collect light in the near-infrared from a million galaxies at a time.

WFIRST's Wide Field Instrument is a 300-megapixel digital camera that records the measurements meant for both the dark energy research and a new statistical survey of exoplanets.

Belief that dark energy makes up so much of the universe is enough, astronomers say, to justify their desire to know more about it.

WFIRST's supernova survey would carry on what Hubble's started, but on a much larger scale, along with more measurements to factor into the expansion history.

Hertz of NASA headquarters explains that WFIRST will stare at a bunch of points in the sky that are loaded with galaxies. WFIRST "will keep coming back to them, regularly looking to see if one of the stars in those galaxies goes supernova," he says. Once a supernova is found, WFIRST will measure how bright it appears. "Because we know how bright supernovae actually are, how bright that supernova looks tells us how far away that galaxy is. And so we can then independently measure the redshift of that galaxy" — the term for how celestial objects shift to the infrared spectrum as they move farther away — "so that we know how fast it's moving away from us."

This gives scientists the distance and the redshift of the supernova. "If we do that for a lot of galaxies, we can map out how fast the universe is expanding. And since the further away we look, the further back in time we're looking, we can convert that map of the expansion of the universe into a description of the expansion history of the universe," Hertz explains. "And so by comparing what the actual expansion of the history of the universe is to what it would be if there was only gravity and there was no dark energy, we can measure the impact of dark energy on the expansion history of the universe."

It's just one of the gaps that the James Webb Space Telescope, now due for launch in spring 2019, with its much narrower field of view, won't be able to fill.

Another is a very big chunk of time.

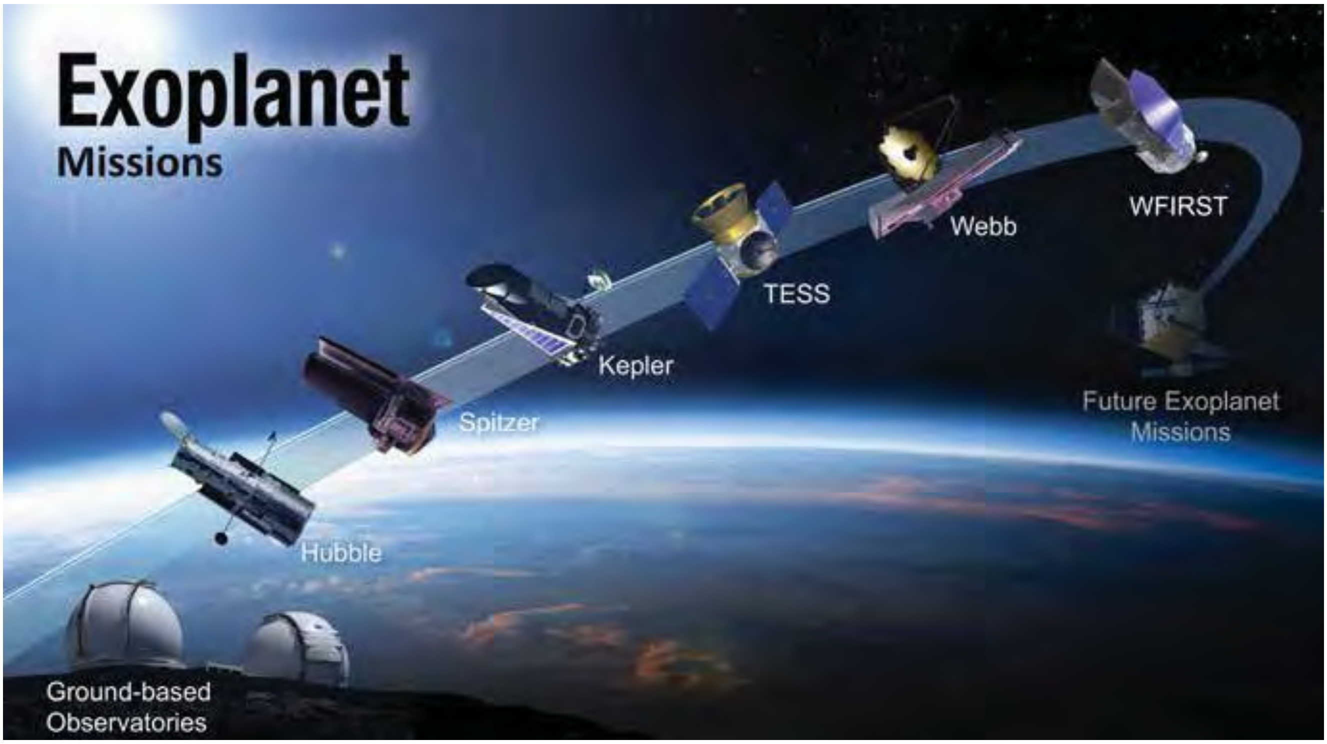
Webb's mission prioritizes the mid-infrared — "wavelengths that are way redder than our eyes can see," Hertz says. "So that's the early universe. Webb is designed to see the first stars and galaxies after the Big Bang."

WFIRST, on the other hand, "operates in the near-infrared, which is just a little bit redder than our eyes can see," providing a look midway back in time.

"If we don't do WFIRST — if the U.S. chooses not to build and launch WFIRST — then we will not make the progress that we need to make to understand

WFIRST VS. EUCLID

Like WFIRST, the European Space Agency's Euclid space telescope will investigate dark energy when it is launched 2021. ESA says Euclid will observe billions of galaxies to investigate the origin of the universe's accelerating expansion and "reveal the signatures of dark energy." The WFIRST and Euclid missions looked similar enough that in 2012 a committee of U.S. scientists considered whether the missions might be redundant while weighing whether the U.S. should have a role in Euclid. WFIRST "had the more robust and powerful approach" and would tackle "more ambitious" measurements, including a supernova survey and observations intriguing to planet hunters, reported the Board on Physics and Astronomy of the National Academies of Sciences, Engineering and Medicine. David Spergel of Princeton University, today's WFIRST co-principal investigator, was chair of the study committee. The U.S. is supplying Euclid's near-infrared detectors.



▲ **Astronomers are looking at NASA's next three telescopes** to help solve mysteries relating to dark energy and where there are planets that might be like Earth.
NASA

dark energy," Hertz says. "There is 15 times more dark energy than there is normal matter in the universe, and we don't understand it, and the National Academy of Sciences has said it was the highest priority science problem that needs to be solved."

Back at Princeton, WFIRST's Spergel says he hopes Congress will follow the decadal recommendation, as it has historically done, versus going along with the White House's plan to redirect WFIRST funds.

"I know in conversations with congressional staffers and conversations with some of the members of Congress, they have said to me they value the decadals," Spergel says. "I hope they continue to support [WFIRST]."

Trump's nominee for NASA administrator, Rep. Jim Bridenstine, R-Okla., was firm on following the decadal recommendations, when asked during his Nov. 1 confirmation hearing. They help policymakers "make good decisions," he said, and added:

"We need to follow the decadals."

All the planets in the galaxy

Why does NASA even need a new exoplanet survey of the galaxy, when the Kepler Space Telescope has already defined the population of planets potentially suitable for human habitation and TESS, the small Transiting Exoplanet Survey Satellite planned for launch this month, is expected to find 20,000 new exoplanet candidates?

"The reason why you want a mission like WFIRST and a mission like TESS is, TESS is most sensitive to exoplanets that are close to the star because they're the ones that are most likely to pass in front of the star and block out a little bit of that star's light," says Hertz, NASA's astrophysics director, describing the technique of transit photometry used by TESS and made famous by Kepler. Such planets are more likely to be in the "habitable zone" at temperatures that allow for liquid water.

Even within its much smaller field of view, Kepler gathered enough data to satisfy scientists that they understand how many close-in planets populate the galaxy. Now TESS will monitor vast swaths of sky to single out possible exoplanets close enough to Earth for follow-up by ground telescopes and the James Webb Space Telescope scheduled to launch in 2019, to try to find out things such as atmospheric composition.

"WFIRST, because it's using a completely different method, will be sensitive to different kinds of planets. So in particular, WFIRST is more sensitive to planets that are far away from their star," Hertz explains — "out in the areas where in our solar system Jupiter and Saturn and Uranus and Neptune reside.

"We don't actually know how common planets are outside of the habitable zone because Kepler was not sensitive to those planets."

The big pictures brought in by WFIRST would enable an observational technique called microlensing — a way of finding planets that's like the reverse of transit photometry.

In WFIRST's microlensing, the gravity of a planet in a totally other solar system from a background star crosses in front of that star and bends and amplifies the star's light. Researchers find the planets statistically, the planets' effects recorded as smaller increases in brightness than those created by their own host stars.

"So you will see the distant star will get brighter, and then start to get faint, and then get a little bit brighter again, and then continue getting faint, and that would indicate that there is a planet around the 'lensing' star — the intermediate star — and so that's how WFIRST will discover exoplanets," Hertz says.

The method is better for finding bigger planets orbiting farther out, as their effects are less likely to get mixed up with those of their stars.

"It will complete the statistical census of exoplanets in our galaxy," Hertz says. "We're not counting every planet, but we're counting enough that we can extrapolate as to the whole population."

First look at an Earth-like world

The gift of the big mirror came with the feasibility of adding another planet-focused instrument that wasn't part of the original plan but which Hertz regards as addressing "one of the most exciting science questions of the day" — namely, how to find life on other planets.

Getting a direct visual image is widely thought to be the surest way of knowing whether a planet is truly Earth-like, says Jeremy Kasdin, principal investigator of the WFIRST coronagraph instrument. Coronagraphs are optics that block out a star's light, revealing planets otherwise shrouded in the glare.

For the first time, a coronagraph in space would have controls to compensate for telescope pointing drift and jitter. Webb's won't, making it a lot less accurate.

NASA reclassified the WFIRST coronagraph as a technology demonstration instrument after an independent review, concluded in 2017, suggested doing so. This lowered classification reduced the required testing load and helped get WFIRST back on budget.

WFIRST's coronagraph is appropriate for photographing giant planets, but capturing a smaller rocky world, like Earth, would require a more powerful telescope. A goal of WFIRST is to demonstrate the technology for a future telescope like that. With a more sensitive telescope and a tried-and-true coronagraph, Kasdin thinks the first photos of Earth-size exoplanets will be possible.

The money part

Spergel at Princeton was surprised by the 2019 budget proposal, but not totally shocked, partly because it's a vulnerable time in the development — the end of Phase A, the concept definition stage in which requirements are set. Some work has been done on long-lead-time components, such as the infrared detector arrays.

> **"If we don't do WFIRST — if the U.S. chooses not to build and launch WFIRST — then we will not make the progress that we need to make to understand dark energy."**
>
> **—Paul Hertz, director of NASA's Astrophysics Division in the Science Mission Directorate**

The original WFIRST, with the smaller mirror, was going to cost $1.6 billion, according to the 2010 projection. A cap was set at $3.2 billion with the addition of the bigger mirror and added capabilities. The independent review concluded last year found that it was on track to cost closer to $3.9 billion, so the coronagraph was reclassified, bringing the estimate back down to $3.2 billion.

In the meantime, the congressional Government Accountability Office has said Webb is likely to exceed its $8 billion cap.

NASA Acting Administrator Robert Lightfoot, before announcing his plan to retire at the end of this month, sent a different message from what members of the astrophysics community are saying.

"I think when you look at the priorities that we have today, that we're still meeting the majority of our science priorities going forward," Lightfoot told a congressional committee in March in defending the cut. "We're going to launch TESS, for instance, this upcoming year. We've got James Webb going out. So the astrophysics area's in pretty good shape from that standpoint."

Later, when pressed on WFIRST, he acknowledged that "the gap in astrophysics data that we would get from WFIRST — I mean, to the astrophysics community, that's a challenge, from a scientific perspective. The positive side of that, though, is that those funds can perhaps get the data in a different way." He said WFIRST is "definitely what the decadal survey has asked for, but we think there's other ways to get that same data."

WFIRST was budgeted for $350 million in 2019. As of early March, Spergel hoped Congress would approve the Senate's budgeted $150 million for fiscal 2018 and thought a thumbs-up vote by Congress could be a good sign. The program had been operating at the 2017 spending level of $105 million.

WFIRST could easily image 1 billion galaxies in its lifetime.

"It would be a great loss to science and a great loss to U.S. leadership in science" if WFIRST were cut, says Hertz, NASA's head of astrophysics. ★

A boost for military spacepl

SpaceX

The U.S. Air Force has long wanted the ability to project conventional weapons and surveillance equipment anywhere in the world in minutes. Despite spending billions on various concepts, the capability has remained elusive. Military space expert Jess Sponable says its time for the service to take a fresh look at the feasibility of spaceplanes for this role.

BY JESS SPONABLE

◀ Two of a Falcon Heavy's three core boosters land at Cape Canaveral Air Force Station in Florida.

The launch of the SpaceX Falcon Heavy in February and the recovery of two of the massive vehicle's three boost stages should cause a tectonic shift in the U.S. Air Force's thinking about the feasibility of building a small fleet of spaceplanes to project eyes, ears and presence globally.

Here's why.

Based on publicly reported information, the recovered stages had an attractively high propellant mass fraction, a calculation of propellant mass over takeoff gross mass. A higher mass fraction enables larger payloads, and when reusability is introduced, this adds up to the potential for enhanced reliability and much lower launch costs per kilogram.

In short, the SpaceX feat suggests that it is now economically viable to construct and operate a new class of vehicle: Global reach military spaceplanes able reach anywhere in the world in under an hour.

Extrapolating into the future is always risky, but the impressive mass properties and public plans of SpaceX, including the planned Big Falcon Rocket or BFR, provide a highly credible roadmap that the Air Force could follow for its own endeavors with contractors.

Military spaceplanes will likely not need the massive payloads of the Falcon Heavy and BFR, instead far smaller vehicles with one or two stages can operate from distributed bases inside the United States. In lieu of SpaceX's launch on schedule, the military spaceplanes would be launched on demand, be fully reusable, turn around in hours and routinely fly to space or overfly any location on Earth. Depending on the mission, they could be designed to glide high within the Earth's atmosphere or fly on top of it at the edge of space. Short single pass missions would enhance survivability in any threat environment.

In terms of physical size and dry weight, both of which drive cost, military spaceplanes scaled down from SpaceX vehicles would be no larger than commercial aircraft. Indeed, the payload/dry weight ratio, a measure of productivity in the

NASA

▲ The Defense Department and then NASA flew the vertical takeoff and landing Delta Clipper Experimental, or DC-X, in the 1990s.

operational systems can potentially be developed at a fraction the cost of many current military aircraft.

Spaceplanes are hardly a new concept. Ever since the Army Air Forces became the U.S. Air Force in 1947, the service has envisioned and invested many billions toward creating global reach spaceplanes. For decades Strategic Air Command (SAC) provided the impetus behind high speed aircraft including the X-15, X-24, XB-70, and the development of spaceplane concepts, including the X-20 DynaSoar and the X-30 National Aero-Space Plane, neither of which flew. The NASP program alone spent over $5 billion in today's dollars, no small investment. In addition, weapons experiments like the Boost Glide and Advanced Maneuvering Reentry Vehicles were flown. Then, with the end of the Cold War, SAC was retired, and its assets were reassigned to other major commands. Also retired, unintentionally, was much of the Air Force's strategic thinking about future weapon systems, and any significant investments to continue the service's heritage of advancing high speed technologies.

SAC had thought about how to fight in a world of nuclear superpowers, growing terrorism, religious and political extremism, the proliferation of weapons of mass destruction, multi-polar powers and technology run rampant. Without SAC, leaders of the reorganized Air Force shifted toward investing in the service's traditional technologies: Superior short-range aircraft and bigger, more exquisite satellites. Equally significant, most investment in the Air Force's high-speed future tailed off, with spending instead focused on improving proven technologies and refining existing approaches.

Thankfully, some work on advanced launch and landing technologies persisted. In the early 1990s, the Strategic Defense Initiative Organization flew the vertical takeoff and landing Delta Clipper Experimental, or DC-X, and then transitioned the technology to NASA, which continued the flights. Ultimately, the vertical takeoff and landing vision was picked up by the commercial sector – Blue Origin and SpaceX – rather than by the military. In the late 1990s, researchers from the Air Force and NASA air dropped a very different experimental vehicle, the Boeing-built X-40, which evolved into the X-37 orbit test vehi-

commercial sector, would be similar to conventional aircraft, suggesting that ultimately costs will be similar as well. Gross weights would be heavier compared to commercial aircraft, but the difference would be largely due to the oxidizer, which only costs about 10 to 15 cents per kilogram and is far cheaper than jet fuel. They would be "spaceplanes" not because they have wings or look like aircraft but rather because they fly with aircraft-like operability, sortie rates, and recurring flight costs.

SpaceX, of course, still flies a small expendable upper stage, and the Falcon 9 and Falcon Heavy are limited by their expendable vehicle origins, but SpaceX's next step, the BFR, aims to be fully reusable. SpaceX is leveraging their design and operational experience to create a future of routine, fully reusable, aircraft-like access to space or any location on Earth. By leveraging the technology and cost efficiency demonstrated by SpaceX and other emerging entrepreneurs, experimental spaceplanes or even cle, essentially a recoverable satellite. In parallel, NASA continued maturing reusable technologies.

Ultimately America's true geniuses, our entrepreneurs, stepped up to the plate. Elon Musk achieved the first big success by flying back a Falcon 9 stage in December 2015, but Jeff Bezos' Blue Origin is not far behind. Even Boeing is investing with DARPA, under the Experimental Spaceplane XSP program, in their Phantom Express spaceplane. .

With DARPA's aggressive goals of very long-life and a high ops tempo of ten flights in ten days, Boeing is arguably the closest to achieving the aircraft-like operability needed for military spaceplanes. Yet other entrepreneurs are maturing expendable launch vehicles with plans to migrate toward reusable systems in the future, like SpaceX. While entrepreneurs innovated, the Air Force began to rekindle its heritage of advancing technologies: in 2014 the service published its 30 year "call to the future" urging airmen to develop global vigilance, global reach, global power capabilities. This vision supports modernizing conventional crewed and unmanned air systems, but every mission and core competency identified, whether intentional or not, also advocated for the capabilities global reach spaceplanes can provide.

Military spaceplanes will likely not need the massive payloads of the Falcon Heavy and BFR, instead far smaller vehicles with one or two stages can operate from distributed bases inside the United States.

Militarizing space

Speaking to the Air Force Association in February, the Air Force chief of staff, Gen. David Goldfein, reportedly warned, "It is not a question of if but when airmen will be fighting in space." He had it partially right. The real issue is not fighting in space but rather flying through or near space to accomplish a myriad of Air Force missions. Launch on demand for augmenting and reconstituting lost capability will be essential, especially in the coming era of proliferating satellite constellations. Launch on demand also enables single pass reconnaissance anywhere on Earth even if our large, exquisite satellites are lost. Such concepts require only a small squadron of global reach sortie vehicles flying with impunity from the United States. Surge flight rates could be implemented when required. The spaceplane fleet could be akin to the 1990s SR-71 fleet of twelve aircraft, only without the vulnerabilities. Spaceplanes could fly and fight through any attack against our space systems. If the future warrants the development of boost glide vehicles to counter those espoused in Vladimir Putin's state-of-his-nation address in March, the U.S. Air Force's military spaceplanes could be optimized for testing and executing such combat missions. Next generation spaceplanes with their global reach, hypersonic speeds, and relative invulnerability to today's air and space defenses will make them invaluable to the Air Force, from Air Mobility Command to every combatant command.

Our ground, sea, air and space assets project our eyes, ears and presence overseas at a combined cost of over $200 billion annually, all before the first shot is fired. Spaceplanes will not replace these assets but over time they can lead the way to a force mix that also emphasizes rapid temporal response and globe shrinking speeds. These are critical attributes for deterring, and when necessary, waging future conflicts.

In a world of proliferating terrorism and nuclear weapons the ability to respond near instantaneously may well be the only credible defense. Whether rapidly replacing lost assets in orbit or flying a single pass reconnaissance mission from the central United States, the response time, relative invulnerability and speed of spaceplanes can be key to deterring the escalation of future conflicts.

If history is a guide, it's far from certain that the U.S. military will decide to develop military spaceplanes. Indeed, the U.S. Army failed to keep up with worldwide developments in aviation for over 30 years after the Wright brothers flew. Instead, the technology was matured overseas where the finest military aircraft were made. It took another world war, massive loss of life, and the greatest generation to shake the U.S. out of our complacency. There is synergy between the entrepreneurial and military needs, but the military cannot change without investment.

If the Air Force is serious about its technological heritage, it needs to step up and invest in a series of X-planes and projects that leverage entrepreneurial investments and pave the way to launch on demand global reach capabilities. The investments should not just be about modernizing Air Force Space Command, they should be about dragging the Combat Air Forces into the space age. Like the U.S. Army, the Air Force has chosen not to invest for over a quarter century. A narrow mission oriented "stovepipe" organizational structure, politics and bureaucratic inertia all drove those decisions, but the SpaceX success with reusable boosters suggests it may be time to rethink that decision. One thing for sure, no bucks, no Buck Rogers. ★

Jess Sponable
left DARPA in November where he was program manager for development of the XSP Experimental Spaceplane. He has supported satellite, launch and spaceplane initiatives and technology development since 1987 as a civil servant, in the private sector and as an Air Force officer before retiring as a lieutenant colonel. Sponable was program manager for the DC-X vertical takeoff and landing rocket in the early 1990s.

REACH EUROP

ING A

The White House wants to steer the launch of NASA's proposed Europa Clipper spacecraft to a commercial rocket, such as the Delta 4 Heavy or possibly the Falcon Heavy. Not so fast, says one powerful congressman. Tom Risen looks at the launch vehicle politics and tradeoffs for what could be one of NASA's most extraordinary endeavors yet.

BY TOM RISEN | tomr@aiaa.org

Space science and technology careers at NASA can push the envelope of one's biological clock. First you have to persuade the agency to fund your idea, and then it can take five years or longer to design and build the spacecraft.

Consider the Europa Clipper probe whose orbit around Jupiter would send it close to the ice-covered moon Europa, and hopefully through what appear in Hubble images to be plumes of water vapor erupting from its surface. Where there is water there could be life or at least the chemical residue from living organisms.

Scientists at NASA's Jet Propulsion Laboratory in California began thinking about visiting Europa in some manner after the Galileo probe in 1997 found evidence for saltwater oceans beneath the icy surface. It took until August 2015 to establish the team that will develop the Europa Clipper mission and make key recommendations such as which vehicle to launch it on.

A tacit debate is playing out these days among officials from NASA, the White House and Congress over which rocket to launch Europa Clipper on sometime between 2022 and 2025.

The commercial options are a United Launch Alliance Delta 4 Heavy or perhaps a SpaceX Falcon Heavy. The government-owned option is a Space Launch System rocket in development for NASA by Boeing, Aerojet Rocketdyne and Orbital ATK mainly for launching astronauts.

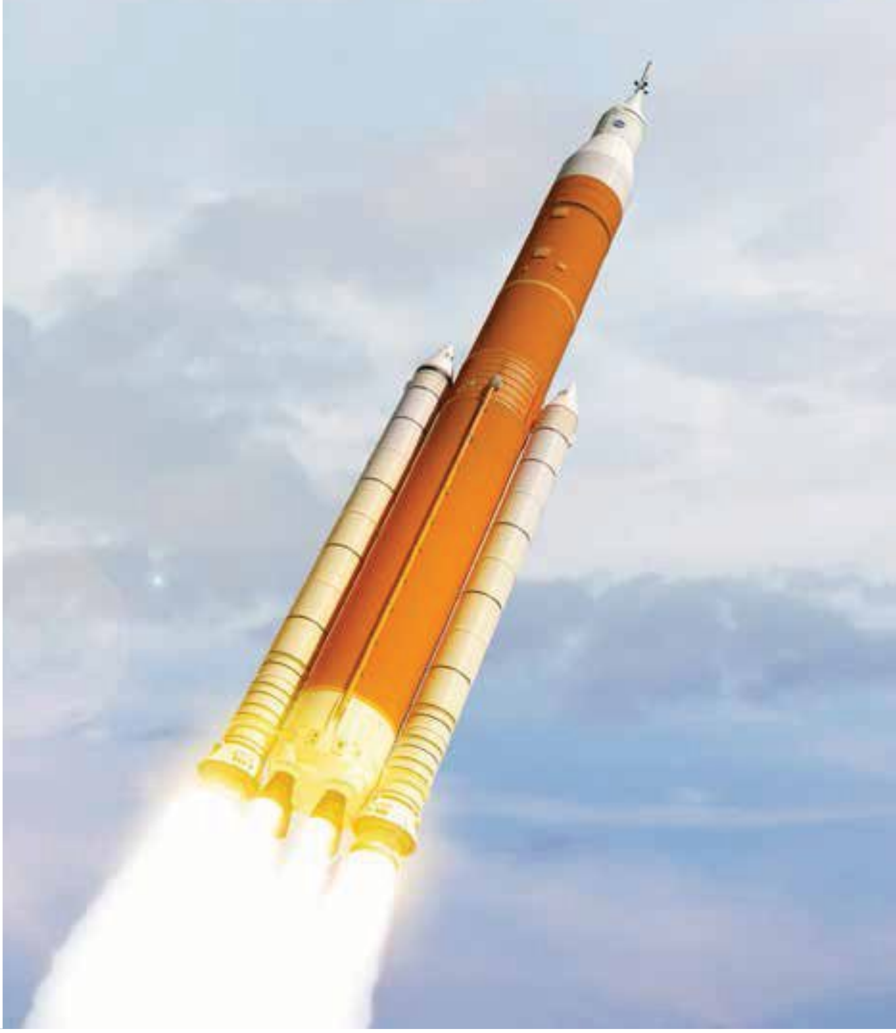
What's the difference? An SLS could get the $4 billion Europa Clipper to Jupiter's orbit in 2½ to three years. Once in space, the rocket's exploration upper stage would blast Clipper directly to an orbit around Jupiter that would take it by Europa every 14 days. NASA says a version of SLS with a less powerful interim cryogenic propulsion stage could also carry Clipper on a direct flight.

A Delta 4 Heavy or Falcon Heavy would take several times longer because the SLS will have more thrust at liftoff from four RS-25 engines and two solid rocket boosters. This means the Clipper would have to orbit Venus to gain momentum for a flight to Jupiter's orbit.

"I'm retiring in a few years, so I won't see it through if it launches on a 7½-year cruise," says

◀ **United Launch Alliance's Delta 4 Heavy rocket** is one of the commercial contenders to send NASA's Europa Clipper into space.
ULA

▲ **SpaceX's Falcon Heavy rocket** is the other commercial candidate.
NASA



Barry Goldstein, the Europa Clipper project manager at JPL.

Normally, a decision about the launch vehicle for a high-profile mission like the Clipper belongs to the NASA administrator. The agency says the NASA leader will decide within a year, subject to any legal direction. NASA Acting Administrator Robert Lightfoot announced he is retiring in April, however, and administrator nominee Rep. Jim Bridenstine, R-Okla., is still waiting for Senate approval.

The clear preference among Clipper scientists would be to fly on an SLS, provided it meets the agency's criteria, but the design has not yet left the ground. "The reliability of SLS depends on maturing manufacturing processes and having a steady cadence of flights. Neither has happened yet," notes Cristina Chaplain, who directs oversight research into space and missile defense work for the congressional Government Accountability Office.

Enter the Trump administration. The NASA portion of the White House budget request for 2019 proposes launching the Europa Clipper on a Delta 4 Heavy or other "commercial launch vehicle," saying this "would be several hundreds of millions of dollars cheaper than an SLS flight." It also bumps the launch to 2025 instead of 2022.

▲ **The Space Launch System** is the government-owned option in development.
NASA

This was an unexpected twist for Europa Clipper scientists and it seems to be headed for a political minefield. The 2017 appropriations bill signed by President Donald Trump requires NASA to "use the Space Launch System as the launch vehicle" for the spacecraft "no later than 2022."

For Clipper scientists, the message from Rep. John Culberson, R-Texas, chair of the House Appropriations subcommittee in charge of NASA, seems to be don't fret. The SLS choice is "not debatable," he tells Aerospace America. Culberson, a strong backer of SLS whose district includes NASA's Johnson Space Center, says he appreciates the White House's passion for space exploration but "the final decisions are made in Congress" through NASA authorization and appropriations bills.

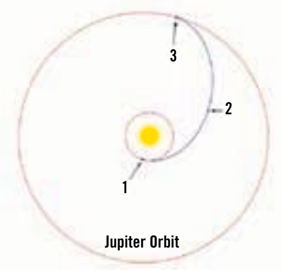
"We'll be able to get science back far more quickly using the SLS," he says. There is urgency to this mission, he adds, because if signs of life are found on Europa, "that is the kind of civilization-level discovery that NASA needs to inject fresh energy, fresh support for the space program, in general."

The SLS has a deep bench of supporters on Capitol Hill. Sens. Richard Shelby, R-Ala., and Bill Nelson, D-Fla., have fought attempts to curtail funding for the SLS rockets. The adapters that will

The choice

NASA wants to find out if the ocean under the ice of Jupiter's moon Europa could support life. The agency is weighing the best rocket and trajectory for putting the Europa Clipper probe into an orbit around Jupiter that would take it by Europa. Here are the options:

FLY DIRECT Arrive in 2.9 years

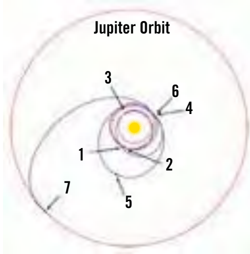


EVENTS

1. **Launch:** June 17, 2022
2. **Deep space maneuver:** March 22, 2023
3. **Jupiter orbital insertion:** May 1, 2025

Tradeoffs: Fast, but requires NASA's Space Launch System rocket, which is still being developed.

GRAVITY-ASSIST OPTIONS Arrive in 7.6 years



EVENTS

1. **Launch**: May 25, 2022
2. **First Earth gravity assist:** May 24, 2023
3. **Venus gravity assist:** Nov. 22, 2023
4. **Second Earth gravity assist:** Oct. 21, 2024
5. **Deep space maneuver:** Oct. 22, 2025
6. **Third Earth gravity assist:** Oct. 22, 2026
7. **Jupiter orbital insertion:** Jan. 15, 2030

Tradeoffs: Could be achieved with less expensive commercial rockets, but takes more than twice as long.

Falcon Heavy | Delta 4 Heavy | SLS Block 1

Source: NASA's Jet Propulsion Laboratory

release payloads to space are being built at NASA's Marshall Space Flight Center in Alabama. In Florida, NASA's Kennedy Space Center, where Nelson once flew from as a shuttle astronaut, has been upgraded as the launch site for the SLS.

There are critics of SLS, too. Delays and cost overruns have drawn criticism from House Science Committee Chairman Lamar Smith, R-Texas, among others. NASA in 2017 pushed the first mission for the rocket, Exploration Mission 1, from 2017 to December 2019. The agency has spent about $8.6 billion on SLS through fiscal 2017 and expects to spend about another $1.2 billion through fiscal 2020.

Given the direction from Congress that was signed off on by Trump, the JPL team continues to prepare Clipper for the 2022 launch deadline set by Congress. Officials there are excited about the prospect of gathering close-up data just a few years after that, if SLS is ready and available.

There could be a big hitch due to SLS's main job of carrying astronauts on exploration missions. "It is not possible to launch the Clipper on an SLS earlier than 2024 without disrupting current NASA human exploration plans," according to the White House 2019 budget proposal.

The request proposes 2025 as the launch date to keep SLS "focused on supporting the administration's new space exploration strategy and prioritizing the return of astronauts to the surface of the Moon."

Exploration Mission 2 scheduled for 2022 to send astronauts to orbit the moon could conflict with Clipper's launch date.

Scheduling is a concern, but NASA and Congress want to maximize flights on the SLS so a broad range of missions make the cost of the rockets worthwhile, says James Knauf, a former U.S. Air Force colonel who served as deputy director of space acquisition at the Pentagon. NASA says it would cost $700 million to $1 billion to launch an SLS rocket, including an exploration upper stage, based on its preliminary estimate, according to NASA's Cheryl Warner. "I don't have a lot of optimism that they are going to be able to bring the SLS launch cost down," Knauf says.

The discussion about launch options reflects how "we are at a crossroads" with the creation of more privately owned heavy lift rockets, says Eric Stallmer, president of the Commercial Spaceflight Federation industry association that represents companies including SpaceX.

"I don't think the White House is anti-SLS," says Stallmer, who is a member of the National Space Council's User Advisory Group, representatives from industry and other non-federal entities that "use" or benefit from aerospace technology. The National Space Council is an executive branch board that

"The reliability of SLS depends on maturing manufacturing processes and having a steady cadence of flights. Neither has happened yet."

— Cristina Chaplain, Government Accountability Office

LIFE ON EUROPA

NASA was so optimistic about the chance for life-supporting conditions on Europa that it concluded the Galileo in 2003 by flying the probe into Jupiter to avoid contamination from a potential crash into the moon.

makes space recommendations to Trump.

"The White House is very keen on the greatest utilization of commercial products when possible," Stallmer says.

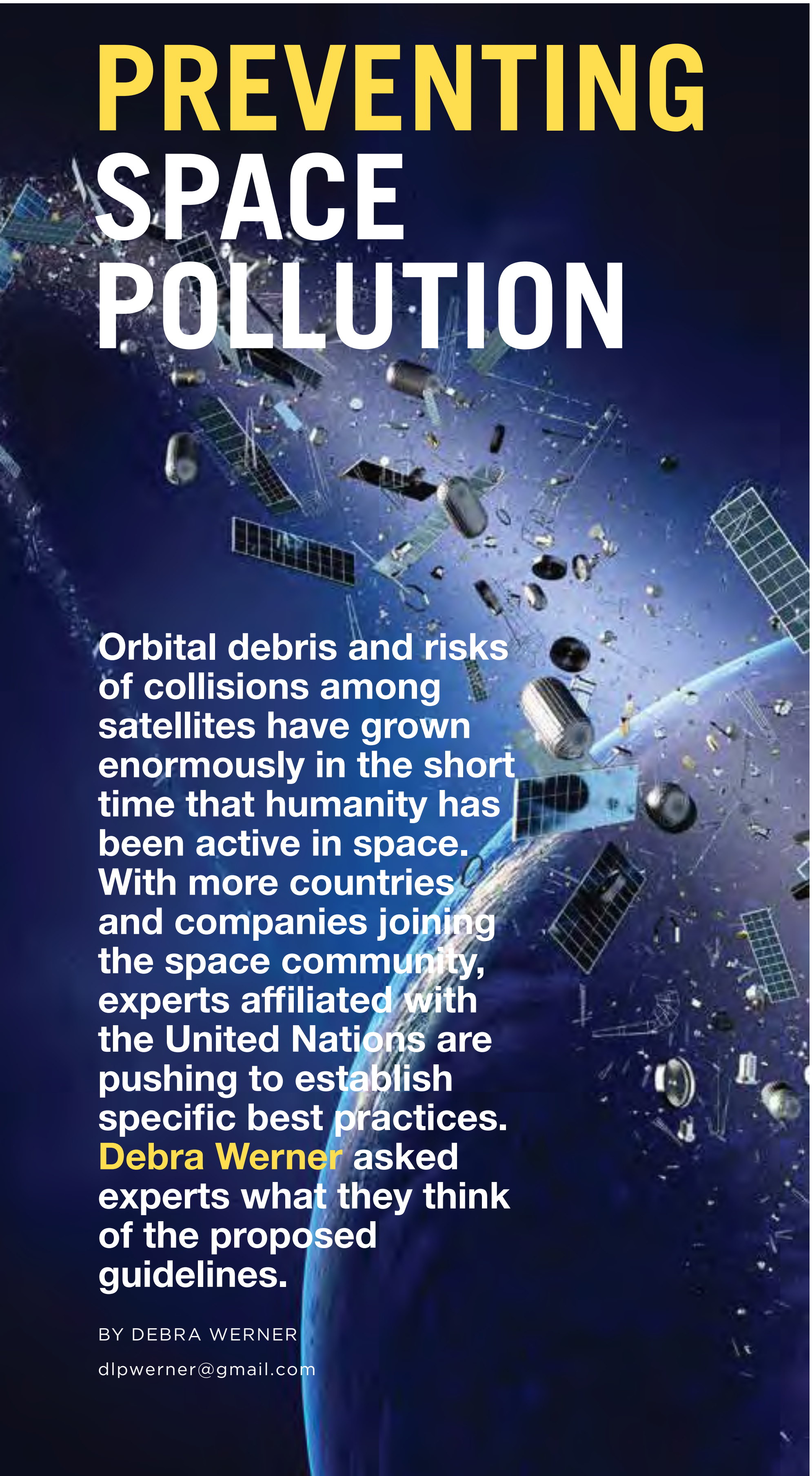
Delta 4 Heavy has been the main contender against SLS, but Clipper officials noted the Falcon Heavy debut launch in February. Goldstein says the performance data from that launch sent by Kennedy Space Center indicates the Falcon Heavy would likewise be unable to fly directly to Jupiter, and would arrive at a similar time as the Delta 4 Heavy by getting a momentum boost after orbiting Venus. Both rockets have a payload fairing large enough to carry the Europa Clipper. SpaceX founder Elon Musk has said a fully expendable Falcon Heavy would cost $150 million per launch. ULA and NASA did not provide launch cost estimates for the Delta 4 Heavy.

Uncertainty about which rocket will launch the Clipper makes designing the probe more challenging and more expensive, Goldstein says. The probe is being designed with additional thermal shielding in case it flies close to Venus on a trajectory to reach the Jovian moon, he says, adding that the preliminary design review for the Clipper is in August.

Flying Clipper on a longer route to Jupiter orbit would also mean spending more on NASA employees to monitor the spacecraft. There are only rough models for that potential expense but it would "definitely be less than the difference in the cost" between SLS and another rocket, says Joan Salute, program executive for Europa Clipper at NASA JPL.

If patience is called for, that won't be something new for the planetary scientists involved with Clipper. Planetary science missions can last 20 years, so their teams often expect not be at NASA for the end of their missions and train replacements to continue operations after they retire.

"Any biogenic material, any bacteria that may be there in the water plumes, will likely be there years from now, so I don't know if there is urgency that requires the SLS to fly Europa Clipper," says Jack Burns, an astrophysicist at the University of Colorado who served on Trump's NASA transition team. ★



PREVENTING SPACE POLLUTION

Orbital debris and risks of collisions among satellites have grown enormously in the short time that humanity has been active in space. With more countries and companies joining the space community, experts affiliated with the United Nations are pushing to establish specific best practices. Debra Werner asked experts what they think of the proposed guidelines.

BY DEBRA WERNER
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Those who are in the business of launching rockets and operating satellites could soon have a set of internationally approved guidelines that are meant to put everyone on the same page about how to be good stewards of the orbital environment. Twenty-one guidelines are scheduled to be assessed in June by the United Nations Committee on the Peaceful Uses of Outer Space, which is expected to pass them to the General Assembly for consideration. The nine newest were approved in February in Austria by a COPUOS working group that included members from China, Europe, Iran, Russia and the U.S. These guidelines join 12 that were approved in 2016 but never passed forward. The working group was formed in 2010, the year after an Iridium communications satellite and a defunct Russian military satellite collided, and three years after China destroyed one of its satellites in an anti-satellite missile demonstration that left thousands of pieces of debris in orbit.

IN THEIR WORDS

1 David Kendall

Now we have a comprehensive set of new guidelines. That is quite remarkable.

These 21 new guidelines are nonbinding and voluntary. This reflects the reality under which COPUOS operates. Many states believe that obtaining agreement on binding treaties is not possible in the near future given geopolitical differences, although there remains the hope that binding instruments on essential issues might be possible after further negotiation and discussion. The process now is to encourage all states and international intergovernmental organizations to take measures to ensure that the guidelines are implemented to the greatest extent feasible and practicable in accordance with their respective needs, conditions and capabilities and with their existing obligations under applicable international law. While one could consider that to be fairly soft, it does have a moral suasion. States that have signed onto these guidelines have an obligation to follow through.

Most people do not understand the complexity of trying to reach agreement at this level of detail. Every word, every dot, every comma was negotiated to ensure consensus. There were times when we threw up our hands and thought, "This isn't going to work." But in the end, it did. We have a committee whose members are working in spite of political differences to ensure the security, safety and sustainability of outer space, to ensure that this global commons is available now and in the future because, if we screw it up, we are in big trouble.

2 Peter Martinez

In well-established spacefaring nations, many of the practices in the guidelines are already accepted practices but they may be rather less well or not at all established in emerging space nations.

The fact that the world space community has been able to agree on any guidelines at all is a step forward. It was a process of getting everyone on the same page first on the importance of this issue and second on the kind of measures we should take to preserve the space environment for current and future generations. This is the first step in what will be an ongoing discussion in COPUOS and in the global space community, including international professional and industry associations.

This is new guidance that supplements the existing guidance in treaties, national laws, standards, etc. The guidelines give some direction, particularly to emerging space actors, about responsible behaviors in outer space. We are very much hoping these voluntary nonbinding guidelines will assist states that are developing their space capabilities and that even established actors will be informed by them in formulating their own space activities.

3 Victoria Samson

You have countries sitting together, the United States, Russia, China, Iran, Canada, Switzerland, with a variety of different interests and concerns. The fact they were able to come to agreement on 21 guidelines is a real win."

Now there are over 60 countries with space capabilities or interests. The use of space is also changing. We are seeing mega-constellations and new activities proposed, like proximity operations and active debris removal. It's good to have rules of the road to ensure that space is usable and sustainable over the long term. That's helpful from an international perspective and also from a U.S. national security viewpoint. All you need is one person to do something either maliciously or, more likely, accidentally that leaves so much debris in an orbit it becomes financially unrealistic for anyone to use it.

The COPUOS process, while lengthy, allows for multiple stakeholders to give input and to voice their concerns.

1

Canadian **David Kendall** has chaired COPUOS, the United Nations Committee on the Peaceful Uses of Outer Space, since 2016. He led science and technology programs in the Canadian Space Agency for eight years.

2

South African **Peter Martinez** chairs the United Nations Working Group on the Long-Term Sustainability of Outer Space Activities. He is director of SpaceLab, a graduate school within the Department of Electrical Engineering at the University of Cape Town.

3

American **Victoria Samson** analyzes military space and security issues in the Washington, D.C., office of the nonprofit Secure World Foundation, headquartered in Colorado.

4

American **John Crassidis** teaches space situational awareness at the University of Buffalo in New York, where he directs the Center for Multisource Information Fusion. He is an AIAA fellow.

5

Jonathan McDowell, a British and American citizen, is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

4 John Crassidis

"Guidelines to limit the amount of debris are good. Obviously, you don't want to put more debris up there. If the Kessler Syndrome keeps going, low Earth orbit is going to essentially be useless to us."

The guidelines are good because they raise awareness. The United Nations is saying this debris problem is important. If some NASA office published the guidelines, they would not get the same exposure.

Some of the guidelines are very pointed. One had to do with laser beams passing through outer space. That's obviously a good one. You don't want to dazzle a satellite by mistake. On other ones, I don't see much cooperation. One guideline calls for countries to perform conjunction assessments during all phases of controlled flight. For a lot of satellites, we don't know if they are going to do a maneuver because they don't belong to us. Yes, it would be good for those countries to share the information on when they are going to do a maneuver but I don't see countries providing that information. I don't see why they'd want to.

Guidelines to limit the amount of debris are good. Obviously, you don't want to put more debris up there. If the Kessler Syndrome keeps going, low Earth orbit is going to essentially be useless to us. People should pay attention to this debris problem because it's going to affect future generations.

5 Jonathan McDowell

"A few percent of satellites are never registered. Most of those are not due to malign intent but due to bureaucratic screw ups or turf wars."

The current registration system established during the Cold War when there were only American and Soviet satellites is inadequate for 21st-century space traffic management when, for example, an Indian rocket launches 100 satellites from many different countries.

The bigger problem is a lack of transparency. That's what the new guidelines try to address. What

GOOD STEWARDSHIP Here is a brief overview of the nine guidelines approved by the U.N. Working Group on the Long-term Sustainability of Outer Space Activities in February. *

The guidelines say that nations and international intergovernmental organizations should:

- Register with the U.N. in a timely manner anything sent into orbit and update the registry when a spacecraft changes orbit, stops working or ejects anything, including small satellites or service modules.
- Exchange updated contact information on organizations authorized to exchange information on spacecraft operations, conjunction assessments and to respond to incident reports and forecasts.
- Find ways to more precisely determine the orbit of space objects and perform conjunction assessments for each spacecraft's current and planned trajectories. Spacecraft operators who are unable to perform conjunction assessments should seek support from state authorities who can assist them.
- Conduct pre-launch conjunction assessments to ensure their spacecraft do not collide with anything during launch.
- Promote and facilitate international cooperation aimed at helping emerging spacefaring countries implement the U.N. guidelines.
- Share expertise and information related to the long-term sustainability of outer space activities.
- Ensure that even very small spacecraft include features that make them easy to track in orbit. Nations and international governmental organizations should encourage spacecraft manufacturers and operators to adhere to national and international space debris mitigation standards.
- Take measures to address risks associated with the uncontrolled re-entry of space objects.
- Take precautions to ensure that laser beams sent through space near Earth do not interfere with other space activities.

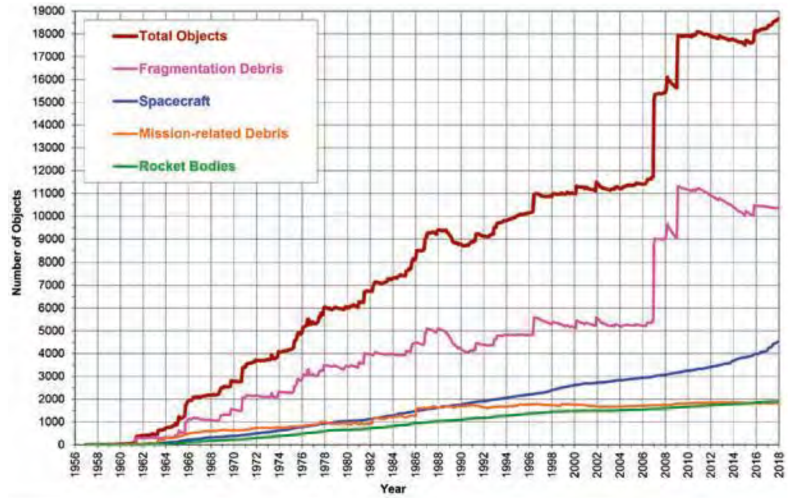
* The complete guidelines are posted at the website of the U.N. Office of Outer Space Affairs, www.unoosa.org.

happens to the satellites after launch? Tell us when you are going to move your satellite so we don't move at the same time and accidently hit you.

The other thing the guidelines say is, "Get your act together before launch to decide who is the launching state" [meaning the country responsible for registering the satellite with the U.N. Office for Outer Space Affairs]. A number of satellites are unregistered because the rocket owner's host country thought the satellite owner's host country should register it and the satellite owner never informed their host country.

It's good that the countries agreed on these policies but there is a lot more work to be done in terms of defining standards and getting people to start adopting them.

NUMBER OF OBJECTS IN EARTH ORBIT BY OBJECT TYPE



Source: NASA Orbital Debris Program Office/Orbital Debris Quarterly

6 Jessica West

"[The guidelines] strike a balance between expecting that everyone will adopt best practices and acknowledging not everyone has the same technical capabilities. I appreciate the attention given to cooperation and technical assistance, because space is growing into an environment with a lot of different actors."

Mostly, the guidelines codify best practice, which is fine because they need to be adopted by everybody. They also strike a balance between expecting that everyone will adopt best practices and acknowledging not everyone has the same technical capabilities. I appreciate the attention it gives to cooperation and technical assistance because space is growing into an environment with a lot of different actors. As access continues to grow, it will be important to have everybody on the same page and applying the same standards.

The guidelines also start to tackle some of the trickier sustainability questions on the horizon concerning small satellites. Do all satellites have to follow the same standards of safety and respect for the environment or do small satellites have a different set of obligations? This sets the stage for a similar set of obligations across all satellites and starts to point toward things that will make it easier to manage traffic in outer space and debris. It points to the fact that small satellites should have tracking sensors which would enable better space traffic management from the ground, particularly if we are starting to talk about these large constellations of satellites that are being planned.

The guidelines are voluntary, but I wouldn't write off the voluntary nature. Most states take their political commitments very seriously and don't see much difference between binding and voluntary commitments.

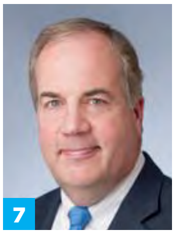
7 Matthew Desch

"This is a reasonable first step, but frankly, much more needs to be done and it lacks 'teeth,' as it all depends on the good will of all parties."

Given our experience in this area, we are very supportive of this U.N. working group effort. This is a reasonable first step, but frankly, much more needs to be done and it lacks 'teeth,' as it all depends on the good will of all parties — many who may not have the incentives to comply. Still, we're encouraged by the work and are hopeful this will help provide a baseline for future operators and constellations. Iridium is already following these guidelines. ★

6

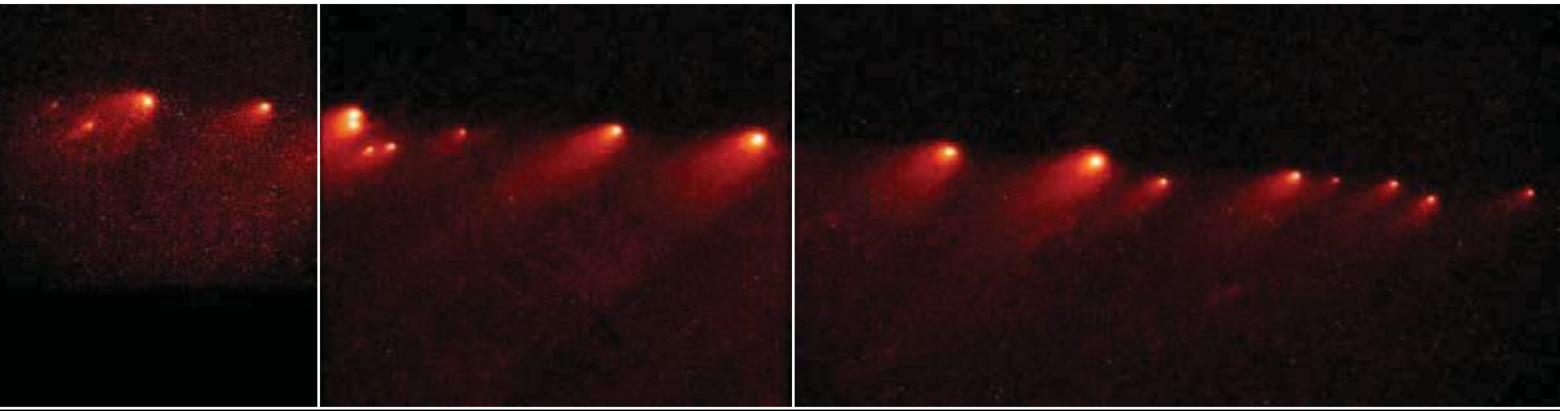
Canadian **Jessica West** manages the Space Security Index, an annual risk assessment produced by experts from Australia, Canada, China and the U.S., under Project Ploughshares, a nongovernmental organization that encourages policies to prevent war.



7

American **Matthew Desch** is CEO of Iridium, a company building the Iridium NEXT constellation of 66 satellites in low Earth orbit. In 2009, one of the company's satellites was struck by a Russian satellite in the first reported incident of a functioning satellite destroyed by an accidental collision.

By Robert L. Marcialis, Nadine G. Barlow and Larry A. Lebofsky



Detonating a nuclear bomb sounds like a common-sense way to protect Earth from a far-off asteroid or comet headed our way. The reality is that the attempt would probably make matters worse, which is why it has been relegated to being a fringe idea. Planetary Astronomers Robert L. Marcialis, Nadine G. Barlow and Larry A. Lebofsky explain.

NUCLEAR NONS

The community of researchers who worry about the issue of dangerous near-Earth objects on a daily basis long ago considered and wisely discarded the nuclear option that is favored in the opinion article, "Earth's Best Defense," in the February issue of Aerospace America. The reasons for this rejection had nothing to do with political correctness and everything to do with analysis, physics, and information shared through a series of Planetary Defense conferences held every two years. Allow us to explain.

Suppose an asteroid, 10 to 50 meters in diameter, were on a collision course with Earth. This is the size of the object referred to in the February article and that created the 1.2 kilometer-wide Barringer Crater near Winslow, Arizona. Such an object would be large enough to cause extensive damage, ballistically throwing ejecta as far as 3 km from the crater.

Let's look at the content and energy of the Barringer object. Made of iron and nickel, it did not vaporize entirely on impact despite megaton estimates for the released energy of up to 60 MT. Many chunks were strewn about the surrounding countryside; many are now in collections. Those observations agree with the results of laboratory studies and numerical modeling that demonstrate how difficult it is to vaporize iron or mixes of iron and nickel. It's therefore incorrect to expect that a nuclear detonation of similar megatonnage could vaporize such an object before it reached Earth.

Instead of neutralizing the threat, we would be left with a fragmented, disrupted body. True reme-

▲ **Pieces of the comet Shoemaker-Levy 9,** sometimes referred to as the string of pearls comet, collided with Jupiter in 1994. This is a series of images from the Hubble Space Telescope.
NASA

NASA/MSFC/Jacobs Technology/ESSSA/Aaron Kingery

diation is more likely if the target is not disrupted, but given a gentle, long-lasting nudge in a controlled manner. Fragmentation would compound our problems enormously. Instead of having to deflect one bullet, we would have a hailstorm of particles, large and small, to dodge. Perturbation of each particle from its original orbit cannot be predicted, and we would have to ensure the entire ensemble misses Earth so as not to compound the damage inflicted. Note that a 10-centimeter wide iron fragment (the size of your fist) can survive atmospheric entry to hit the ground, heating and producing shock waves in the atmosphere on its way down. The 2013 Chelyabinsk bolide (estimated to be initially 20 meters in diameter) attests to how seriously damaging these shock waves can be.

Fragments of this body would be imparted with a range of kinetic energies and would drift apart. If detonation occurs at 1 AU and 100 days before Earth encounter, the cloud would have expanded to 17,000 km, or 1.35 Earth diameters. To ensure that this cloud misses Earth, we would have to ensure a deflection of at least 2.6 Earth radii (the radius of the cloud, plus the gravitational radius of Earth), plus a 50 percent safety margin, or nearly 4 Earth radii.

Dispersal also would occur along the trajectory, not just normal to it. A single impact here on Earth would become a string of impacts lasting more than an hour.

Note that a near miss is not acceptable risk. The threat avoidance problem is much more complicated. Here's why: If the mutual orbits of Earth and the object intersect at one point in time, they will intersect at other times in the future. Fragments will continue to

▲ **Comet Lovejoy and its tail are visible in this three-minute exposure.** At the time of this image in 2013, Lovejoy was 37 million miles from Earth, very near to its closest approach.

AIAA/IEEE ELECTRIC AIRCRAFT TECHNOLOGIES SYMPOSIUM

12–13 JULY 2018 | DUKE ENERGY CONVENTION CENTER, CINCINNATI, OH

The aerospace industry has set ambitious goals for the next three generations of commercial transport aircraft to accommodate rapid growth in emerging markets and ensure the future sustainability of air travel. One approach being explored to meet these targets is nontraditional aircraft propulsion using electric, turboelectric, or hybrid-electric powertrains.

Recent workshops by the IEEE and AIAA have identified the need to bring together electrical engineers and aerospace experts as the industry looks to more electric propulsion technologies for future aircraft. The AIAA Aircraft Electric Propulsion and Power Working Group, the IEEE Transportation Electrification Community, and the College of Engineering of the University of Illinois at Urbana-Champaign are collaborating to organize a new two-day symposium to address these issues. The event occurs on 12–13 July, following the AIAA Propulsion and Energy Forum.

The symposium will focus on electric aircraft technology across three programmatic tracks: (1) electric-power enabled aircraft configurations and system requirements, (2) enabling technologies for electric aircraft propulsion, and (3) electric aircraft system integration and controls. Abstracts are solicited in specific areas of relevancy including, but not limited to, the following:

TRACK 1

Aircraft Configurations & Systems Requirements

- System feasibility studies
- Electric-enabled innovative aircraft design and propulsion concepts
- Electrical powertrain performance requirements
- Safety, critical failure modes, certification
- Lifecycle energy, operational cost, and emission analysis

TRACK 2

Enabling Technologies

- Machines and drives integration for optimum performance
- Conventional, cryogenic, and superconducting
- Fault tolerant power systems and components
- Energy storage devices and systems
- Electric machine and gas turbine engine integration
- New material solutions or applications
- Novel thermal management solutions
- Verification and testing

TRACK 3

System Integration and Controls

- Electric powertrain architectures
- Fault isolation and reconfigurable systems
- Energy management systems
- Integrated electro-thermal systems
- System modeling tools
- Monitoring and diagnostics

All papers will be co-published in both AIAA's electronic library, Aerospace Research Central (ARC), and the IEEE Xplore digital library. In addition, the EATS organizing committee may recommend high-quality papers for journal publication and is exploring the development of an invited special edition publication in a relevant AIAA or IEEE journal, covering the most impactful work presented at EATS.

For complete symposium details visit:
aiaa.org/EATS

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Tourists look into the Barringer Crater from the edge near Winslow, Ariz. Scientists estimate an asteroid 10 to 50 meters in diameter caused the crater.

U.S. Geological Survey

disperse even after the Earth encounter, becoming an ever-widening debris cloud. Tidal forces (the tendency of objects in a gravity gradient to drift apart with time), the Yarkovsky effect (the slight thrust caused by solar heating and re-radiation of thermal IR by the evening hemisphere), radiation pressure, and perturbations by other bodies of the inner solar system will constrain what constitutes a successful change in trajectory. Each of these stochastically adds to what comprises an acceptable "miss."

Metallic bodies actually comprise only a small minority (about 4.5 percent) of the population of interplanetary bodies, as shown by the distribution of meteorites recovered from Antarctica. Much more probable is that the threatening body would have a stony composition. From the sample of asteroids and comets visited by spacecraft, representative porosities of these bodies are a few tens of percent. These bodies are most likely agglomerations of chunks, large and small. Any impulsive change in momentum is likely to fragment the body rather than deflect its trajectory, because it is mechanically weak.

There is overwhelming evidence that the average object is mechanically weak. Consider Comet Shoemaker-Levy 9's impact with Jupiter in 1992. The comet was torn into 21 fragments merely by tidal forces in a previous encounter with Jupiter. For stony objects, including most asteroids and all comets, the "rubble pile" description is most appropriate.. Gravity and mechanical strength are close to zero. If you push a bucket of sand, it moves as a whole. Not the case for a sand castle. Should a stony object be headed our way, it is likely a wash between the kinetic impactor and a nuclear detonation: either would simply fragment the body.

Whether an object is stony or metallic, a failed first attempt at deflection by a nuclear device in all probability eliminates any chance of success on subsequent tries, even should sufficient time exist. The debris from the first attempt would produce what amounts to a field of kinetic energy weapons around the body. At an approach velocity of 11 km/sec, impact on the delivery vehicle by a rice-sized particle would be catastrophic to the vehicle and the odds of mission success.

Our best path to success depends on early detection and cataloging of potentially hazardous bodies, combined with knowledge of the physical properties of such a body, both keys to designing a reasonable course of action.

Here's a sampling of the many methods of gentle diversion that have been proposed over the last couple of decades:

- Sending a massive satellite close to the body as a "gravity tractor" to pull the threat in a calculated and controllable direction.
- Landing a similar satellite on the surface of the body and pushing the threat with high specific impulse, low thrust rocket motors in the desired direction.
- Physically painting parts of the body's surface with reflective and/or absorptive coloring.
- Orbiting a satellite equipped with lasers, which would vaporize select regions on the surface of the body, producing an in situ thrust.

These are just a few of the ways we can intervene. The reality is that the nuclear option is no option at all. ★

A more detailed version of this article is available at http://bit.ly/2pfWLI8.

Robert L. Marcialis is a visiting scientist at the University of Arizona's Lunar and Planetary Laboratory in Tucson and an AIAA senior member. He holds a doctorate in planetary science from the University of Arizona and a Bachelor of Science in aeronautical and astronautical engineering from MIT. Email umpire@lpl.arizona.edu

Nadine G. Barlow chairs the Department of Physics and Astronomy at Northern Arizona University in Flagstaff. She holds a doctorate in planetary sciences from the University of Arizona. Email nadine.barlow@nau.edu

Larry A. Lebofsky is a senior education and communications specialist at the Planetary Science Institute in Tucson, Arizona, and an AIAA senior member. He has a doctorate in earth and planetary sciences from MIT. Email lebofsky@lpl.arizona.edu

Aerospace Spotlight Awards Gala

Wednesday, 2 May 2018
Ronald Reagan Building and International Trade Center
Washington, D.C.

Please celebrate with esteemed guests and colleagues in Washington, D.C., when AIAA recognizes individuals and teams for outstanding contributions that make the world safer, more connected, and more prosperous.

Presentation of Awards

- **AIAA Goddard Astronautics Award**
  Gwynne E. Shotwell
  President and Chief Operating Officer
  SpaceX
- **AIAA Reed Aeronautics Award**
  Mark Drela
  Kohler Professor of Fluid Dynamics
  Director, Wright Brothers Wind Tunnel
  Massachusetts Institute of Technology
- **AIAA Distinguished Service Award**
  Mary L. Snitch
  Senior Manager, Global S&T Engagement
  Lockheed Martin Corporation
- **Daniel Guggenheim Medal**
  Paul M. Bevilaqua
  Manager, Advanced Development Programs
  Lockheed Martin Corporation (retired)
- **AIAA Public Service Award**
  George C. Nield
  Associate Administrator for Commercial Space Transportation
  Federal Aviation Administration
- **Lawrence Sperry Award**
  Michael D. West
  Assistant Director
  Australian Department of Defence
- **AIAA Foundation Award for Excellence**
  To Be Announced
- **Class of 2018 Fellows and Honorary Fellows**

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We are frequently asked how to submit articles about section events, member awards, and other special interest items in the AIAA Bulletin. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the AIAA Bulletin Editor.

Calendar

Notes About the Calendar

For more information on meetings listed below, visit our website at aiaa.org/events or call 800.639.AIAA or 703.264.7500 (outside U.S.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2018			
6 Apr	DirectTech Webinar—Thermal Modeling and Regenerative Cooling of Liquid Rocket Engines	Virtual (aiaa.org/onlinelearning)	
26 Apr	DirectTech Webinar—Electric Aircraft Design Fundamentals: Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft	Virtual (aiaa.org/onlinelearning)	
1 May	2018 Fellows Dinner	Crystal City, VA	
2 May	Aerospace Spotlight Awards Gala	Washington, DC	
8–10 May	AIAA DEFENSE Forum (AIAA Defense and Security Forum) Featuring: – Missile Sciences Conference – National Forum on Weapon System Effectivenss – Strategic and Tactical Missile Systems Conference	Laurel, MD	30 Nov 17
10–11 May	Aerospace Survivability Course	Laurel, MD	
28–30 May †	25th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru)	
28 May–1 Jun †	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	6 Jul 17
31 May	DirectTech Webinar—High Order CFD Methods: Results and Advancements from the 5th International Workshop	Virtual (aiaa.org/onlinelearning)	
4–8 Jun†	DATT (Defense & Aerospace Test & Telemetry) Summit	Orlando, FL (www.dattsummit.com)	
23–24 Jun	Design of Electric and Hybrid-Electric Aircraft Course	Atlanta, GA	
23–24 Jun	Missile Aerodynamics Course	Atlanta, GA	
23–24 Jun	Optimal Design in Multidisciplilnary Systems Course	Atlanta, GA	
23–24 Jun	Practical Design Methods for Aircraft and Rotorcraft Flgiht Control for Manned and UAV Applications with Hands-on Training Using CONDUIT® Course	Atlanta, GA	
23–24 Jun	5th AIAA Workshop on Benchmark Problems for Airframe Noise Computations (BANC-V)	Atlanta, GA	
25–29 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – AIAA/CEAS Aeroacoustics Conference – Aerodynamic Measurement Technology and Ground Testing Conference – Applied Aerodynamics Conference – Atmospheric Flight Mechanics Conference – Atmospheric and Space Environments Conference – Aviation Technology, Integration, and Operations Conference – Flight Testing Conference – Flow Control Conference – Fluid Dynamics Conference – Joint Thermophysics and Heat Transfer Conference – Modeling and Simulation Technologies Conference – Multidisciplinary Analysis and Optimization Conference – Plasmadynamics and Lasers Conference	Atlanta, GA	9 Nov 17
25–29 Jun†	15th Spacecraft Charging Technology Conference (SCTC)	Kobe, Japan (Contact: http://www.org.kobe-u.ac.jp/15sctc/index.html)	
3–6 Jul†	ICNPAA-2018 - Mathematical Problems in Engineering, Aerospace and Sciences	Yerevan, Armenia (Contact:: www.icnpaa.com)	
7–8 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Cincinnati, OH	
7–8 Jul	Fundamentals of Gas Turbine Engine Aerothermodynamics, Performance, and Systems Integration Course	Cincinnati, OH	
7–8 Jul	Liquid Atomization, Spray, and Fuel Injection in Aircraft Gas Turbine Engines Course	Cincinnati, OH	
7–8 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, and Emerging Technologies Course	Cincinnati, OH	

†Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/Co-SponsorshipOpportunities.

AIAA Continuing Education offerings

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
7–8 Jul	Propulsion of Flapping-wing Micro Air Vehicles (FMAVS) Course	Cincinnati, OH	
7–8 Jul	AIAA Complex Aerospace Systems Exchange (CASE) Workshop	Cincinnati, OH	
7–8 Jul	4th Propulsion Aerodynamics Workshop	Cincinnati, OH	
8 Jul	Enabling Technologies and Analysis Methods for More-, Hybrid-, and All-Electric Aircraft Course	Cincinnati, OH	
9–11 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – Joint Propulsion Conference – International Energy Conversion Engineering Conference	Cincinnati, OH	4 Jan 18
12–13 Jul	AIAA/IEEE Electric Aircraft Technologies Symposium	Cincinnati, OH (aiaa.org/eats)	15 Feb 18
19–23 Aug†	2018 AAS/AIAA Astrodynamics Specialist Conference	Snowbird, UT (www.space-flight.org)	
17–19 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition) Featuring: – Complex Aerospace Systems Exchange – International Space Planes and Hypersonic Systems and Technologies Conference	Orlando, FL	8 Feb 18
1–5 Oct†	69th International Astronautical Congress	Bremen, Germany	
2019			
7–11 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – Adaptive Structures Conference – Aerospace Sciences Meeting – Atmospheric Flight Mechanics Conference – Information Systems — Infotech@Aerospace Conference – Dynamics Specialists Conference – Guidance, Navigation, and Control Conference – Modeling and Simulation Technologies Conference – Non-Deterministic Approaches Conference – Space Flight Mechanics Meeting – Structures, Structural Dynamics, and Materials Conference – Spacecraft Structures Conference – Wind Energy Symposium	San Diego, CA	11 Jun 18
13–17 Jan†	29th AAS/AIAA Space Flight Mechanics Meeting	Ka'anapali, HI	14 Sep 18
2–9 Mar†	2019 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
3–5 Apr†	5th CEAS Conference on Guidance, Navigation & Control (2019 EuroGNC)	Milan, Italy (Contact: www.eurognc19.polimi.it)	
27–29 May†	26th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: www.elektropribor.spb.ru/icins2019/en)	

Recognizing Top Achievements— An AIAA Tradition

For over 80 years, AIAA has been committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. AIAA celebrates the pioneering spirit that is showcased by the following individuals who were recognized between October 2017 and January 2018.

Presented at the Joint Conference of the AIAA International Communications Satellite Systems Conference (ICSSC) and the Ka and Broadband Communications Conference (Ka)

16–19 October 2017, Trieste, Italy

AIAA Aerospace Communications Award

Stuart T. Linsky
Vice President, Engineering and Global Product Development, Northrop Grumman Corporation
For technical leadership, innovation and development of protected satellite communications systems.
Nominated by: Ron Smith, Northrop Grumman Aerospace Systems.

Presented at the 33rd Society for Gravitational and Space Research Annual Meeting

25–28 October 2017, Renton, Washington

AIAA Space Processing Award

Mark M. Weislogel
Portland State University
For decades of leadership in Space Shuttle and ISS zero-g fluids scientific experimentation and global public outreach via design and publicity of creative fluids activities onboard ISS.
Nominated by: Jeff G. Marchetta, University of Memphis

Presented at the AIAA SciTech Forum

8–12 January 2018, Kissimmee, Florida

Durand Lecture for Public Service

C. D. Mote, Jr.
President, National Academy of Engineering
"NAE's Grand Challenges for Engineering and the Scholars Program"

Dryden Lectureship in Research

Graham V. Candler
McKnight Presidential Professor and Russell J. Penrose Professor, University of Minnesota
"Advances in the Simulation of High-Speed Combustion Flows"

Aerospace Design Engineering Award

NASA/Boeing PRSEUS Development and Test Team

Received by Dawn Jegley, Team Primary NASA Langley Research Center
In recognition of excellence in developing and demonstrating damage arresting composites technology in a Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS).
Nominated by: Damodar Ambur, NASA Langley Research Center

Aerospace Guidance, Navigation and Control Award

Mark J. Balas
Professor, Embry-Riddle Aeronautical University
For sustained excellence in developing the frontiers of theory and practice in advanced adaptive control systems for complex and dynamic systems.
Nominated by: Mark Whorton, The University of Tennessee Space Institute

de Florez Award for Flight Simulation

Laurence Retman Young
Professor, Massachusetts Institute of Technology
Distinguished researcher responsible for fundamental contributions in applying quantitative models of human perception and control to enhance flight simulation motion and visual cueing.
Nominated by: John Tylko, Aurora Flight Sciences Corporation

Intelligent Systems Award

Kevin A. Wise
Senior Technical Fellow, The Boeing Company
For his long history of developing intelligent autonomy and integrating intelligent systems into production aerospace systems.
Nominated by: Christine Belcastro, NASA Langley Research Center

Integrated Computational Materials Engineering (ICME) Prize

Julie Tomasi, Will Pisani, Chinkanjanarot, Aaron Krieg, David Jaszczak, Julie King, Ibrahim Miskioglu, Greg Odegard
Michigan Technical University
and
Evan Pineda, Brett Bednarcyk, Sandi Miller
NASA Glenn Research Center
Modeling-driven damage tolerant design of graphene nanoplatelet/carbon fiber/epoxy hybrid composite panels for full-scale aerospace structures

Mechanics and Control of Flight Award

Hanspeter Schaub
Professor, University of Colorado Boulder
For the far-reaching theoretical and practical advances in spacecraft guidance, navigation and control, particularly in the fields of relative motion and nonlinear attitude dynamics and control, as well as space debris remediation dynamics.
Nominated by: Jeffrey Forbes, University of Colorado

Structures, Structural Dynamics and Materials Award

Dewey H. Hodges
Professor, School of Aerospace Engineering, Georgia Institute of Technology
For exceptional contributions to structures, structural dynamics and aeroelasticity of rotary- and fixed-wing aircraft including seminal research advancements and publications, and academic mentoring of outstanding aerospace engineers.
Nominated by: Earl Dowell, Duke University

Survivability Award

Vincent Volpe
Research Staff Member, Institute for Defense Analyses
For pioneering efforts as founding member of AIAA Survivability Technical Committee and more than 40 years of outstanding technical contributions to aircraft survivability community.
Nominated by: Mark Couch, Institute for Defense Analyses

Diversity & Inclusion Award

AIAA Guidance, Navigation Control (GNC) Technical Committee

Represented by: Lesley A. Weitz
Principal Simulation Modeling Engineer, The MITRE Corporation
For significant contributions to AIAA diversity and inclusion as a champion of women's leadership and technical advancements in guidance, navigation, and control systems.

Abe M. Zarem Award for Distinguished Achievement in Astronautics

Langston L. Williams
Graduate Research Assistant/AEP Facilitator, Auburn University
Nominated by: Joseph Majdalani, Auburn University

Abe M. Zarem Educator Award

Joseph Majdalani
Professor, Auburn University

Faculty Advisor Award

Farhan Gandhi
Professor, Rensselaer Polytechnic Institute
For reviving the AIAA RPI Student Branch, facilitating seminars, astronaut visits, company tours, conference participation, and providing students opportunity, exposure, and sense-of-community through the association with AIAA.
Nominated by: Onkar Sahni, Rensselaer Polytechnic Institute

J. Leland Atwood Award

Hanspeter Schaub
Professor, University of Colorado at Boulder
For seminal contributions and recognition for his innovation, elegance, dedication, enthusiasm and impact as an aerospace educator to the University of Colorado at Boulder

Gardner-Lasser Aerospace History Literature Award

Margot Lee Shetterly
Author, HarperCollins Publishers
Hidden Figures
Nominated by: Alivia Lopez, HarperCollins Publishers

History Manuscript Award

Amy Kaminski
NASA Headquarters
"Sharing the Shuttle with America: NASA and Public Engagement After Apollo"
Nominated by: William Barry, NASA

Pendray Aerospace Literature Award

Josette R. Bellan
Senior Research Scientist, Jet Propulsion Laboratory, California Institute of Technology
For widely reaching, seminal and outstanding publications on bio-fuels, sprays and high pressure flows to meet future challenges of Aeronautics and Astronautics combustion systems.
Nominated by: Ashwani K. Gupta, University of Maryland

Summerfield Book Award

Leland Nicolai
Lockheed Martin Corporation (retired)

Grant Carichner
Lockheed Martin Corporation (retired)

Authors of *Fundamentals of Aircraft and Airship Design*
Nominated by: Edward H. Allen, Lockheed Martin Corporation

Learn more about the AIAA Honors and Awards program at aiaa.org/HonorsAndAwards

Annual Business Meeting Notice

Notice is hereby given that the Annual Business Meeting of the American Institute of Aeronautics and Astronautics will be held at the Crystal City Hilton Hotel, Arlington, VA on Wednesday, 2 May 2018, at 1:00 PM.

Christopher Horton,
AIAA Governance Secretary

Nominate Your Peers and Colleagues!

Do you know someone who has made notable contributions to aerospace arts, sciences, or technology? Bolster the reputation and respect of an outstanding peer—throughout the industry **Nominate them now!**

Candidates for SENIOR MEMBER

- Accepting online nominations monthly

Candidates for ASSOCIATE FELLOW

- Acceptance Period begins 15 December 2017
- Nomination Forms are due 15 April 2018
- Reference Forms are due 15 May 2018

Candidates for FELLOW

- Acceptance Period begins 1 April 2018
- Nomination Forms are due 15 June 2018
- Reference Forms are due 15 July 2018

Candidates for HONORARY FELLOW

- Acceptance period begins 1 January 2018
- Nomination forms are due 15 June 2018
- Reference forms are due 15 July 2018

"Appreciation can make a day – even change a life. Your willingness to put it into words is all that is necessary."
– Margaret Cousins

For more information on nominations: aiaa.org/Honors

AIAA
Shaping the Future of Aerospace

CONGRATULATIONS AIAA CLASS OF 2018 FELLOWS AND HONORARY FELLOWS!

"AIAA Fellows and Honorary Fellows have dedicated themselves and their careers to the advancement of aeronautics and astronautics. Their hard work, innovative spirit and leadership have made possible scores of noteworthy aerospace achievements—large and small—during the past decades. AIAA congratulates the members of the 2018 Class of Fellows and Honorary Fellows on their selection."

James Maser, AIAA President

2018 HONORARY FELLOWS

H. Norman Abramson
Southwest Research Institute (retired)

Charles Elachi
California Institute of Technology

Antony Jameson
Stanford University

2018 FELLOWS

Nancy F. Andersen
Johns Hopkins University Applied Physics Laboratory

Supriya Banerjee
FAMES

Olivier A. Bauchau
University of Maryland

Marty K. Bradley
The Boeing Company

Edward L. Burnett
Lockheed Martin Corporation

Carissa B. Christensen
Bryce Space and Technology, LLC

Jonathan E. Cooper
University of Bristol

James E. Graf
Jet Propulsion Laboratory

Michael A. Hamel
Lockheed Martin Corporation

Vlad J. Hruby
Busek Co. Inc

Parimal H. Kopardekar
NASA Ames Research Center

Eugene Lavretsky
The Boeing Company

Sankaran Mahadevan
Vanderbilt University

Mark D. Maughmer
Pennsylvania State University

Robert E. Meyerson
Blue Origin LLC

Dava J. Newman
Massachusetts Institute of Technology

Robert W. Pitz
Vanderbilt University

Stephen A. Rizzi
NASA Langley Research Center

Hannes G. Ross
IBR Aeronautical Consulting; EADS Military Aircraft (retired)

Robie I. Samanta Roy
Lockheed Martin Corporation

Steven P. Schneider
Purdue University

Steven D. Young
NASA Langley Research Center

All AIAA Fellows and Honorary Fellows, you are cordially invited to join us to celebrate the Class of 2018 at the AIAA Fellows Dinner.

Tuesday, 1 May 2018
Hilton Crystal City, Arlington, Virginia

Reception: 1830 hrs
Dinner: 1930 hrs
Attire: Business
Tickets: $130/each

By Invitation Only

More information and registration: aiaa.org/FellowsDinner2018

AIAA
Shaping the Future of Aerospace

Astronaut Stories Australia Fosters Interest in the Aerospace Industry

Contributors:
Abhijeet Kumar, Benjamin Morrell, Liam Heidt, Bhavraj Thethy, Brock Little

In fall 2017 the AIAA Sydney Section organized Astronaut Stories Australia, a series of public outreach events designed to connect students, researchers, and the public with leading icons of the space industry to increase public interest in space-based activities and the wonder of space, as well as motivating support of scientific and technical exploration. The events took advantage of the large number of astronauts who came to Australia for the International Astronautical Congress (held in Adelaide in late September).

Events were planned in Canberra, Sydney, Melbourne, and Brisbane, and each event included an astronaut to headline a STEM workshop for high school students and a large public presentation. The student event (From STEM to Space) was designed to spark an interest in STEM careers. The events included a presentation and Q&A with a panel of astronauts and local STEM role models, followed by hands-on science and engineering activities. The public event (An Evening of Astronaut Stories) aimed to foster a passion and interest for space activities. An astronaut shared stories from their career and from when they were in space, followed by an audience Q&A session.

The events had a tremendous turnout: over 1,000 students participated in the STEM events and 5,000 individuals, including a large number of children, participated in the evening events.

Canberra Event

The first event was held on 19 September at the University of New South Wales Canberra. Col. Pamela Melroy spoke to 70 students from eight schools about the technical engineering challenges that she faced in space and the simple ingenuity that is required of astronauts to come up with simple fixes to challenging problems. She was joined by five other aerospace professionals who answered insightful questions from the students about physics in space, what the hypersonic regime entails what career pathways lead to a career in space, and the role of artificial intelligence in space. This was followed by a rocket activity where students had to design the fin and nosecone of their air-powered rocket with design considerations and constraints based on maneuverability and stability. They were introduced to rocket physics and what would help the rocket reach the highest altitude possible. The next activity entailed spaceship design with Dr. Sean Tuttle (ESA Rosetta engineer), which focused on systems integration, followed by a session on trajectory design with Dr. Doug Griffin and Prof. Andrew Neely, which focused on launch, travel, and reentry of spacecraft heading to Mars.

The evening event, hosted by SQNLDR Marija Jovanovich, included a presentation by Col. Melroy followed by a Q&A where many children had the chance to ask questions. Numerous audience members expressed profound wonder and excitement at the end of the event where human spaceflight, advocacy and policy, career pathways, and space exploration were discussed. The event was livetweeted, which meant there was good engagement throughout the Canberra community.

Sydney Event

The Sydney STEM event took place on 21 September with Col. Melroy, Dr. Sandy Magnus, Dr. Sydney Do, and Mr. Warwick Holmes participating, and included 180 students from eight schools. The panelists spoke about their career journey and STEM education, trying to inspire students from a lower socioeconomic background to explore science and technology. The students participated in activities involving programming Arduinos, virtual reality, a Mars Yard, and a spacewalk. Feedback from the program suggested that the students were inspired to select a high math level or science unit for their school courses after the program and saw a life for themselves in the STEM disciplines.

Five hundred people attended the evening event where Col. Melroy and Dr. Magnus were hosted by Dr. Fred Watson. After an introductory presentation, there was a Q&A session where questions ranged from the technical to the aspirational.

Melbourne Event

On 20 September, "From STEM to Space Melbourne" took place at Science-Works, Museums Victoria. One hundred students from 10 schools from low socioeconomic areas attended the entire program. A further 600 students from 14 schools around Victoria attended a portion of the program via video conference. The program was split into a rocket workshop run by the Australian Youth Aerospace Association (AYAA), where the students learned to conduct the hands-on design and manufacture of chemical rockets, and a talk by either Tony Antonelli or Dorin Prunariu about their experience as astronauts. The students were allowed to explore the Science-Works museum during the lunch break to see the range of exhibits on display. Noting the problem of gender balance and equal representation in engineering today, a broader goal of the Melbourne event was to attempt to achieve a balance in gender, and about 65% of the students were female. The volunteers were an equal 50-50 representation of male and female. By targeting females at a young age, the sections hopes to encourage more of them into STEM roles.

A VIP Night was held on 20 Sep-

tember with members of Museums Victoria and representatives from the aerospace industry, including Boeing, DST Group, BAE Systems, Nova Systems, RAeS, Monash University, RMIT, and the University of Melbourne. An Evening of Astronaut Stories Melbourne (with Tony Antonelli) was held on 23 September in conjunction with the AstroLight Festival. About 1,600 attendees were at the festival, and the Amphitheatre was completely full with the talk being livestreamed to other areas of the festival. The children in the audience were encouraged to ask questions and Antonelli emphasized the importance of math and science in school and made a big impression on the children. The final event of the evening was a panel event focused on "Space Science in 2030" with Dr. Sarah Wittig (European Space Agency), Dr. Gail Iles (formerly ESA and now RMIT) and Dr. Katie Mack (University of Melbourne). Incoming AIAA Melbourne Section Chair Dr. Daniel Edgington-Mitchell moderated the panel. Topics ranged from black holes and space travel to the importance of women in STEM. AIAA also ran an information booth at the AstroLight festival and were happy to have more than 80 individuals interested in future events.

Brisbane Event

On 3 October, "From STEM to Space Brisbane" took place at the University of Queensland (UQ) St. Lucia campus. Seventy-three students from five schools attended the program, which included a talk from panelists, including astronaut Christer Fuglesang, on how the panelists had transitioned from secondary school to a STEM career. There was a strong career focus, with discussions on the practical steps to pursue a STEM career and the skills required to do so. The students also had the opportunity to design, build, and launch rockets, with the help of Kate Dent from AYAA. This project was similar to the one at Canberra and Melbourne and students needed to design and integrate fins, nosecone, and a parachute, so that their rocket would reach the highest altitude possible. Fuglesang watched the rocket launches, asking questions about the designs and talked with the students about how the performance compared with their predictions. The students also had a chance to tour the university's Civil Engineering Labs, Additive Manufacturing Labs, Super-orbital Expansion Tube Laboratory, and UQ Racing Workshop.

That evening at Astronaut Stories Brisbane approximately 270 attendees listened to a short address about the STEM careers available at UQ before Fuglesang spoke to the audience about his experiences and then answered questions with TV science presenter Lee Constable.

Volunteer Committee

To organize these events, students working with the AIAA Sydney Section formed a national committee that worked with teams in each city. The 20 committee members also had a large team of about 60 other volunteers across the four cities. The events benefited from partnerships with different organizations: Scienceworks in Melbourne provided the venue for the events, and combined the events with their Astrolight Festival; the Museum of Applied Arts and Sciences in Sydney hosed the STEM event and coordinated the STEM workshop; Sydney Ideas helped host the Sydney evening events; and the Australian Youth Aerospace Association ran the events in Brisbane and the STEM activities in Melbourne.

Event sponsors were the Royal Aeronautical Society (national partner) and local sponsors were the University of Queensland, University of Sydney, University of NSW Canberra, and Monash University.

Chris Zimmer

Thirteen AIAA student members have been named winners of Aviation Week Network's award program: Tomorrow's Engineering Leaders: The 20 Twenties.

The award recognizes students who are nominated by their universities on the basis of their academic performance, civic contribution, and research or design project. The winners were honored during Aviation Week's 61st Annual Laureate Awards on 1 March at the National Building Museum in Washington, DC. At the event, AIAA President-Elect John Langford, CEO and President of Aurora Flight Sciences, a Boeing Company, was honored with a Lifetime Achievement Award, and AIAA corporate members SpaceX and Boeing were named as Grand Laureate of the Space and Defense divisions, respectively.
(More details can be found at: aiaa.org/2018-Laureate-Awards-and-20-Twenties-Winners)

Call for Papers Now Open for the 29th Space Flight Mechanics Meeting

The 29th Space Flight Mechanics Meeting will be held 13–17 January 2019 at the Sheraton Maui Resort & Spa in Ka'anapali, HI. The conference is organized by the American Astronautical Society (AAS) Space Flight Mechanics Committee and cosponsored by the AIAA Astrodynamics Technical Committee. Manuscripts will be accepted based on their quality of the extended abstract, the originality of the work and/or ideas, and the anticipated interest in the proposed subject. The abstract deadline is **14 September 2018.** Complete manuscripts are required before the conference. Full details can be found at the website: http://space-flight.org/docs/2019_winter/2019_winter.html.

Working Across Different Disciplines—Society and Aerospace Technology Integration and Outreach Committee

By: Dr. Amir S. Gohardani, SAT IOC, Chair

Following the latest face-to-face meeting of the Society and Aerospace Technology Integration and Outreach Committee (SAT IOC) at the 2018 AIAA SciTech Forum in January, SAT IOC is following up its objectives to identify impacts of technology on society. A sequential approach for the committee is to mirror the findings from potential studies into these topics. SAT IOC is actively pursuing a variety of different activities and will have several sessions at the 2018 AIAA SPACE Forum in September (for more information, go to space.aiaa.org/getalerts).

Most recently, additional updates have also been made to the SAT IOC webpage as the committee explores collaborative efforts with other AIAA IOCs and technical committees. A red thread that runs through most SAT IOC activities is the multidisciplinary topics that enable a more all-inclusive vantage point about the aerospace technologies impacting society. SAT IOC is committed to facilitate knowledge transfer between different subject areas and share those findings with the general public.

From left to right: Mary Ellen Eagan, Roy Hawkins, Dirk Speas, and T.J. Schulz

AIAA/ACC/AAAE Speas Award Presented in March

On 1 March, the 2018 AIAA/AAAE/ACC Jay Hollingsworth Speas Airport Award was presented to the **Gerald R. Ford International Airport Authority** during an awards luncheon at the 2018 AAAE/ACC Airport Planning, Design and Construction Symposium. The airport authority was recognized for an innovative and sustainable stormwater and deicing treatment system that provides an example to other airports in meeting operational, regulatory and community needs. Roy Hawkins, planning engineer, accepted the award.

The Speas award was established in 1983 and is presented annually to the nominee(s) judged to have contributed most significantly in recent years to the enhancement of relationships between airports and/or heliports and their surrounding environments via exemplary innovation that might be replicated elsewhere.

AIAA Journals Announcement

To leverage advances in publishing technology, AIAA has been transitioning our technical journals away from the traditional print format over the past few years. This process will be complete in January 2019. *Journal of Aircraft (JA), Journal of Guidance, Control, and Dynamics (JGCD), Journal of Spacecraft and Rockets (JSR), Journal of Propulsion and Power (JPP)*, and *Journal of Thermodynamics and Heat Transfer (JTHT),* will be the last of the journals to move to an online-only format in 2019. The final 2018 issue for each of these journals will be the last issue distributed in print.

Print customers transitioning to the online format will be able to maximize the user experience with research tools and access to the most up-to-date versions of articles in Aerospace Research Central. All of AIAA's technical journals will continue to publish high-quality, original research papers spanning the spectrum of aerospace science and technology and reporting on the most critical aerospace advances.

Obituaries

AIAA Associate Fellow D'Urso Died in February

Steven J. D'Urso died on 16 February. He was 65 years old.

Mr. D'Urso graduated from the University of Illinois at Urbana-Champaign (UIUC) with a B.S. in Mechanical Engineering (1978). He also earned an M.S. degree in Aeronautical and Astronautical Engineering (1989) through the special off-campus graduate program that the UIUC Aerospace Engineering (AE) department delivered to McDonnell-Douglas in the 1980s.

After graduation he accepted a position with Boeing Seattle as a design engineer specializing in structural and mechanical design. During his three years in Seattle he contributed to the design of the Boeing 767 aircraft. In 1980 he joined the McDonnell Aircraft Company as a Technical Specialist for configuration design before being promoted to Senior Principal Engineer and then to a Senior Systems Manager. It was during this time period that he made significant contributions to the Joint Strike Fighter competition. In particular, he produced a fuselage re-design of the X-32 that eliminated the "ugly moniker" associated with that aircraft.

During his time at McDonnell Aircraft, Steve demonstrated his natural teaching abilities early by developing and teaching three aircraft design related courses that were taught as part of the McDonnell Voluntary Improvement Program (Aircraft Configuration Design, Unigraphics I and II 3-D Design, Design for Manufacturability). Additionally, while at McDonnell-Douglas Mr. D'Urso made biweekly visits to the UIUC campus to assist Professor Ken Sivier with the teaching of the AE senior design courses. He also served on the AE Academic Advisory Board from 1991 to 2011 and was its VP (1995–1996) as well as president (1997–2000). Additionally, he served on the UIUC College of Engineering Advisory Board (1997–2000).

After his retirement in 2011 as Senior Systems Engineer/Manager at The Boeing Company, Mr. D'Urso returned to UIUC as a Lecturer and Program Coordinator for Aerospace Systems Engineering in the Aerospace Engineering Department. He organized and initiated the latter undergraduate and graduate programs. He also taught the two-semester senior aeronautical design capstone courses as well as a course systems engineering. His courses were convincing mixture of theory and rich contributions based on his many years of industrial experiences. Additionally, he advised undergraduates and graduates in special research courses and also supervised graduate thesis students.

Mr. D'Urso was an active member of the International Committee on System Engineering (INCOSE). As an AIAA Associate Fellow, he was actively engaged in research and a frequent paper contributor at AIAA conferences. He co-authored a book chapter and a number of significant research papers. Mr. D'Urso also was an active member on and contributor to the AIAA System Engineering Technical Committee.

Among his achievement awards are the McDonnell-Douglas Teammate of Distinction (1991) and Leadership Award (1992); the UIUC AE Department Outstanding Recent Alumnus Award (1994) and Distinguished Alumnus Award (1998); and the Boeing Integrated Defense Systems Performance Awards (2000, 2003) and Leadership Award (2007).

AIAA Associate Fellow Barnard Died in February

Harry R. Barnard, age 82, died on 25 February.

Barnard attended Texas A&M University, earning his degree in Aerospace Engineering (1962). He earned his masters degree in Aerospace Engineering from Southern Methodist University (1969).

In the 1960s, he worked at General Dynamics, Bell Helicopter, and LTV Aerospace Corporation before moving to Texas Instruments where he was an aerodynamic project engineer for the 155 mm Cannon Launched Guided Projectile Program among other projects. In 1983, he moved to Lockheed Martin Missiles and Fire Control as a Lockheed Martin Fellow. He was experienced in the design, analysis, and testing of guided missiles, gun fired guided projectiles and pilotless aircraft. His tasks included aerodynamic coefficient determination, aerodynamic and inertial loads determination, flight dynamics, wind tunnel testing, autopilot and control system analysis, six-DOF simulation, rocket, turbojet, pulsejet and ramjet performance analysis, aero-elastic analysis and aerodynamic heating analysis. He taught Lockheed Martin in-house courses related to missile/aircraft propulsion, missile/aircraft conceptual design and aerodynamics.

Mr. Barnard was also an adjunct professor at the University of Texas at Arlington. He was a member of the AIAA Gas Turbine Engines Technical Committee and supported both local and national AIAA activities.

USC University of Southern California

USC Faculty Position

The University of Southern California, invites applications for tenure-track or tenured positions in the Department of Astronautical Engineering in the Viterbi School of Engineering. We seek outstanding faculty candidates for positions at any rank. The USC Viterbi School of Engineering is committed to increasing the diversity of its faculty and welcomes applications from women, underrepresented groups, veterans, and individuals with disabilities. Outstanding applicants who have demonstrated academic excellence and leadership, and whose past activities document a commitment to issues involving the advancement of women in science and engineering may also be considered for the Lloyd Armstrong, Jr. Endowed Chair, which is supported by the Women in Science and Engineering (WISE) Program endowment.

We invite applications from candidates knowledgeable in astronautical engineering, and will focus on a candidate's promise and/or track record during the review process. Areas of interest include but are not limited to space and rocket propulsion, astrodynamics, and space environment and science, with particular priority in the propulsion area. We seek outstanding individuals who will participate in the university's research and engage with graduate and undergraduate students. Successful candidates will establish a strong, externally funded, research program of national prominence while contributing the core teaching mission of the department. An earned doctorate in a field closely related to Astronautical Engineering is required.

Applications must include a letter clearly indicating area(s) of specialization, a detailed curriculum vitae, a concise statement of current and future research directions, a teaching statement, and contact information for at least four professional references. Applicants are encouraged to include a succinct statement on fostering an environment of diversity and inclusion. Please apply at https://astronautics.usc.edu/facultypositions/. This material should be submitted by June 1, 2018; applications received after this date might not be considered. Interested individuals are welcome to contact Chair of the Faculty Search Committee, Professor Joseph Kunc (kunc@usc.edu).

The USC Viterbi School of Engineering is among the top tier of engineering schools in the world. It counts 185 full-time, tenure-track faculty members, and is home to the Information Sciences Institute, two National Science Foundation Engineering Research Centers, a Department of Energy EFRC (Energy Frontiers Research center), and the Department of Homeland Security's first University Center of Excellent, CREATE. The school is affiliated with Alfred E. Mann Institute for Biomedical Engineering, the Institute for Creative Technologies and the USC Stevens Center for Innovation. Research expenditures typically exceed $185 million annually.

USC is an equal opportunity, affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation gender identity, national origin, protected veteran status, disability, or any other characteristic protected by law or USC policy. USC will consider for employment all qualified applicants with criminal histories in a manner consistent with the requirements of the Los Angeles Fair Chance Initiative for Hiring ordinance.

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3. **Explore More Opportunities –** AIAA has deep relationships with the most respected and innovative aerospace companies in the world. They look to our membership for the most qualified candidates. As an AIAA member, you get access to our **Career Center** to view job listings and post your resume to be seen by the best companies in the industry.
4. **Publish Your Work –** If you are searching for the best place to publish or present your research, look no further! AIAA has five targeted **forums**, eight specifically focused **journals**, and a number of co-sponsored conferences to choose from. Find your peers, publish your work and progress in your career!
5. **Save Money –** Get free access to all our **standards documents** and get discounts on forum registrations, journal subscriptions and book purchases. These savings can quickly pay for your membership!

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AIAA

1918

April 1 The Royal Air Force forms when the British Army's Royal Flying Corps and the Royal Naval Air Service merge. It is the world's first independent air force. David Baker, **Flight Flying: A Chronology**, p. 110.

April 13 An airplane crosses the Andes for the first time. Argentine army Lt. Luis Candelaria piloted the Morane-Saulnier monoplane. Francis Mason and Martin Windrow, **Know Aviation**, pp. 20-21.

April 21 Baron Manfred von Richthofen, the highest scoring ace of World War I, is shot down and dies at Sailly-le-Sec in the Somme Valley, France, soon after he gains his 80th victory in the air. Also known as "the Red Baron," he is shot down by Australian anti-aircraft fire as his bright red Fokker Dr. 1 triplane flies low over the front lines. Francis Mason and Martin Windrow, **Know Aviation**, p. 21; **Flight**, April 25, p. 453.

1943

April 2 The Research Building of the Army Air Forces School of Aviation Medicine officially opens. It contains four high-altitude decompression chambers and is staffed by 27 officers and 35 civilians. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 45.

April 11 The California Rocket Society tests the first hybrid (combination solid-fuel and liquid-fuel) rocket propulsion system in the U.S. The system uses liquid oxygen and a carbon rod. Bernard Smith, a former member of the American Rocket Society, is one of the principal experimenters. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 45;

April 12 The War Department discloses the first details of the formerly secret Norden bombsight. The sight consists of three metal spheres; one contains a gyroscope and another a telescope fitted with cross-hairs that have to be aligned on the target. No description is given on the third sphere. The sight is said to automatically stay on the target irrespective of the speed or movement of the aircraft. **The Aeroplane,** April 23, p. 472.

April 13 Sixteen of the nation's leading airframe manufacturers, representing about 90 percent of the country's warplane output, form the National Aircraft War Production Council at a meeting in Los Angeles. Glenn Martin is elected first president of the Washington-based organization which, among other things, is to coordinate the free exchange of information among companies to avoid duplication and delay; to facilitate cooperation with the armed services; and to expedite the pooling of facilities and plans for increasing the efficiency of wartime aircraft manufacture. **Aero Digest**, May, p. 457.

April 15 British Intelligence sources inform Prime Minister Winston Churchill of reported German experiments with long-range bombardment rockets. These are the A-4, or V-2, projectiles, which are subsequently deployed against London and other targets in 1944. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 45.

April 16 Seeds of rubber trees are dropped by parachute in remote Belgian Congo plantations to speed up the production of rubber, which is badly needed in the war. **The Aeroplane**, April 23, 1943, p. 472.

April 18 Famed Japanese Adm. Isoroku Yamamoto, the mastermind behind the attack on Pearl Harbor, is killed when his Mitsubishi G4M "Betty" bomber is intercepted and destroyed by a flight of U.S. Army Air Forces Lockheed P-38s led by Capt. Thomas Lanphier and Lt. Rex Barker. The two are credited with the victory. Allied intelligence had intercepted and decoded Japanese messages that revealed details of Yamamoto's flight. David Baker, **Flight and Flying: A Chronology**, p. 281.

April 28 Brig. Gen. Frank Lackland, after whom Lackland Air Force Base is named, dies at 58. Born in Fauquier County, Virginia, he joined the Army in 1911 and in 1917 transferred to the Aviation Section of the Signal Corps. He later became an air officer at Kelly Field, Texas; commanding officer of the 1st Wing, March Field, California; and commandant of the Air Force Advanced Flying School at Kelly Field. Lackland Air Force Base is the Army Air Forces' main training base for new recruits. **U.S. Air Services**, May 1943, p. 18.

During April 1943
Consolidated Aircraft, formed by Maj. Reuben Fleet, celebrates its 20th anniversary. A pioneer in the development of large flying boats such as the classic PBY Catalina, Consolidated also produced such notable aircraft as the Fleet biplane, the PB2Y Coronado, and the B-24 Liberator bomber. As it completes its 20th year, the company merges with Vultee to form the Consolidated Vultee Aircraft Corp. **Aviation**, April 1943, pp. 122-125, 404.

North American Aviation president J.H. "Dutch" Kindelberger announces that his company's P-51 Mustang is being adapted as a dive-bomber. Designated A-36, the dive-bomber version is fitted with four hydraulically operated dive brakes. Each wing has a bomb rack to hold either bombs or droppable fuel tanks. **Aero Digest**, April 1943, p. 311.

1968

April 3 Harold Rosen, assistant manager of Hughes Aircraft Co.'s Space Systems Division and manager of Hughes Satellite Systems Laboratories, is named as the recipient of AAIA's first Aerospace Communications Award for his "leadership in making synchronous satellite communications a global reality." NASA, **Astronautics and Aeronautics**, p. 77.

April 4 The unmanned Apollo 6 (ASA-502) mission is launched from Cape Kennedy in Florida to qualify the Saturn 5 vehicle for future manned flights for Project Apollo. Among the objectives this launch is to demonstrate are the translunar injection capability of the Saturn 5 with a simulated payload equal to about 80 percent of a full Apollo lunar spacecraft, and a repeat demonstration of the command module's heat shield capability to withstand a lunar re-entry. This is NASA's final unmanned qualifying mission. But unlike Apollo 4's near-perfect launch and mission, Apollo 6's flight is plagued with problems. At launch, an oscillation ruptures igniter fuel lines in J-2 engines in the second and third stages. The guidance system shuts down two second-stage engines early and the third-stage engine operates at less than optimum performance, preventing the vehicle from achieving its desired parking orbit. Also, in readiness for translunar injection, the S-IVB third stage fails to restart. Nonetheless, 10 hours after launch, the craft lands 80 kilometers from its planned touchdown point in the North Pacific Ocean. Even with the engine failures, Apollo 6 provides NASA with enough confidence to use the Saturn 5 for manned launches. **Washington Post**, April 5, p. A18; **Aviation Week**, April 8, p. 29.

April 7 The Soviet Union launches its Lunik, or Luna 14 spacecraft, toward the moon. On April 10, the spacecraft enters into a lunar orbit. The spacecraft provides data for studies of the interaction of the Earth and lunar masses, the lunar gravitational field, the propagation and stability of radio communications to the spacecraft at different orbital positions, solar charged particles and cosmic rays, and the motion of the moon. It is later revealed, however, that the primary goal of the flight is to test communications systems in support of a planned piloted lunar landing project, although this is never carried out. In addition, ground tracking of the spacecraft's orbit allows controllers to accurately map lunar gravitational anomalies in order to predict trajectories of future lunar missions. **New York Times**, April 8, p. 1.

April 9-10 Electronic signals on the medical condition of U.S. Marine Corps volunteer patients in Tokyo are transmitted among Tokyo, Houston and Washington, D.C., via Intelsat-2 F-2, to demonstrate how worldwide diagnosis of complex medical problems may be achieved by advanced communications satellites. **Washington Post**, April 11, p. A15.

April 17 NASA's Marshall Space Flight Center awards a contract to the industrial design firm Raymond Loewy/William Smith Inc. to conduct habitability studies of planned Earth orbital space stations. The basic goal is to ensure that the stations are comfortable and functional structures in which to live and work. Many years earlier, the French-born Loewy had designed the "Transportation of Tomorrow" exhibit in the Chrysler Motors Pavilion at the 1939-1940 New York World's Fair, which included a rocket ship that would travel between New York and London. Loewy later believed that his most significant project was his work with NASA when, from 1967 to 1973, he was retained as a habitability consultant for the Saturn-Apollo and Skylab projects. His recommendations for Skylab include a window through which astronauts can see Earth. NASA, **Aeronautics and Astronautics, 1968**, pp. 86-87.

April 22 Representatives of 43 nations sign a space rescue treaty in separate ceremonies in Washington, D.C., London and Moscow. The treaty, which had been unanimously approved by the United Nations General Assembly on Dec. 19, 1967, provides for the assistance of astronauts or cosmonauts in emergencies and for their safe return and the return of space hardware. U.S. Secretary of State Dean Rusk, with President Lyndon Johnson in attendance, signs for the United States. NASA, **Astronautics and Aeronautics, 1968**, pp. 89-90.

1993

April 8 Astronaut Ellen Ochoa becomes the first Hispanic-American woman in space as a crew member on the space shuttle Discovery, mission STS-56. Ochoa is an expert with the shuttle's 15-meter remote manipulator arm. She is responsible for operating the arm to lift the $6 million free-flying SPARTAN satellite and place it into orbit. SPARTAN has two telescopes to study the sun's halo and the solar wind, which often interferes with radio communications and navigation systems on Earth. After two days of deployment, the SPARTAN is retrieved by Ochoa with the manipulator arm and placed back in the shuttle's cargo bay for return to Earth so that scientists can study its data. **NASA, Astronautics and Aeronautics**, 1991-1995, pp. 346, 350-351, 701.

DANIEL GILLIES, 33

Rocket Lab USA, mission management and integration director

Daniel Gillies was planning to become an astrophysicist until a competition in his suburban Philadelphia middle school showed him how much fun it was to build things. Gillies now works at Rocket Lab headquarters in Huntington Beach, California, helping customers send small satellites into low Earth orbit on the 17-meter-tall Electron rocket. Rocket Lab, a U.S. company with a wholly owned subsidiary in New Zealand, where it operates a launch site, charges about $5.7 million to launch 150 kilograms. In January, Rocket Lab sent three cubesats into low Earth orbit on its second test flight.

How did you become an aerospace engineer?

Around sixth grade, we had a Future City Competition. It's focused on civil engineering and architecture with a lot of planning and design. I loved it. My math teacher said, "You should think about engineering," and told me what her husband did as an engineer. I got my undergraduate degree in aerospace engineering at Purdue. [After I graduated,] NASA was beginning to award the contract for the Orion space capsule, and I didn't want to miss an awesome phase of U.S. aerospace development. I became a flight controller for United Space Alliance in Houston and got operational experience, sitting on console and doing operations training with astronauts. It was exciting work but I never touched the real hardware. When the space shuttle program was ending, it was hard for Boeing to hire people for a program that was scheduled to end in a couple of years. But for me as a young engineer, it was perfect. I did five years with Boeing as a space shuttle mechanical engineer, a CH-47 helicopter design engineer and a 787 manufacturing engineer. At that point, SpaceX was ramping up its commercial operations prior to the first Falcon 9 fairing flight. I joined as a mission integrator and worked my way to mission manager for the space station commercial resupply missions. The mission manager role is superinteresting because you get to interact with every part of the company and external customers. After SpaceX, I did that work at Spaceflight Industries in Seattle, focusing on rideshare missions [where small satellites ride into orbit alongside larger ones]. Once the first flight of Rocket Lab's Electron went off, I thought, "Now is the time for me to move in while the company is still young and help develop a new sector, small dedicated launch."

Imagine the world in 2050: What do you think will be happening in space?

Right now, I view what we do as a logistics function, although it's still very much treated like a specialized engineering function. By 2050, it's my goal to help eliminate part of my job, the mission integration function, so that going to space is truly as routine as everyone wants it to be. When you want to get a satellite to orbit, you will bring in a package just like going to FedEx. There may be some white glove level of service for particularly sensitive payloads, but I fully expect universities and companies to be able to pack up their payloads and ship them off for a launch to space. I think there will be a large number of vehicles operating in space and we will have a more multimodal architecture. I expect by 2050, you will have a wide variety of options to get to orbit with small and large launch vehicles addressing their respective markets. The space industry will have in-space transportation services to the moon, to asteroids, or wherever they need to go. ★

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